



*SAV Restoration Handbook:
A Guide for Restoring SAV on DOD Installations*





*SAV Restoration Handbook:
A Guide for Restoring SAV on DOD Installations*



Contents

ACRONYMS AND ABBREVIATIONS IX

FOREWORD XI

PREFACE XIII

ACKNOWLEDGMENTS XV

SCIENTIFIC TERMS XIX

CH 1: SAV BASICS 1–1

What Is SAV 1–1

Factors That Influence SAV Distribution and
Growth 1–3

SAV Abundance – A Historical Perspective 1–8

Efforts to Restore SAV 1–10

A Model SAV Program 1–12

CH 2: SAV SURVEYS AND GROUNDTRUTHING 2–1

Historic Distribution of SAV 2–1

Current Distribution of SAV 2–4

Groundtruthing 2–5

 Groundtruthing Equipment 2–8

 Groundtruthing Protocol 2–9

CH 3: HABITAT EVALUATION 3–1

Physical Habitat Parameters 3–2

 Waves and Currents 3–4

 Water Depth and Tides 3–6

 Sediment Characteristics 3–7

Biotic Parameters 3–8

Water Quality Parameters 3–13

 Choosing Parameters to Measure 3–14

 Light 3–14

 Other Water Quality Parameters 3–18

Selecting Monitoring Sites 3–19

Sampling Frequency and Duration 3–19

 Monthly Sampling 3–19

 Biweekly and Weekly Sampling 3–21

 Continuous Sampling 3–22

 Post-Restoration Sampling 3–22

Equipment and Laboratory Requirements 3–24
 Sampling Protocol 3–26
 QA/QC 3–28
 Data Management Protocols and
 Data-Sharing Provisions 3–29

CH 4: RESTORATION 4–1

Benefits of Restoration 4–1
 Planning the Restoration Project 4–2
 Clearly Stating Goals and Objectives 4–3
 Identifying Potential Restoration Sites 4–4
 Identifying Suitable SAV Species 4–5
 Conducting Preliminary Trials 4–9
 Developing a Restoration Design 4–11
 Coordinating Staff and Volunteers 4–17
 Health and Safety Considerations 4–18
 Conducting Post-Restoration Monitoring 4–20
 Developing Data Management and
 QA/QC Procedures 4–21
 Additional Activities That Support Restoration 4–22

CH 5: OUTREACH AND EDUCATION 5–1

Recruiting and Involving Volunteers 5–2
 Sources of Volunteers 5–2
 SAV Grow-Out 5–6

Planting SAV 5–6
 Monitoring 5–7
 Involving the Media 5–7
 Collaboration and Partnering 5–8

CH 6: CASE STUDIES 6–1

Langley Air Force Base 6–2
 Background 6–2
 Assessment and Site Selection 6–3
 Restoration 6–5
 Indian Head Naval Warfare Center 6–9
 Background 6–9
 Assessment and Site Selection 6–9
 Restoration 6–11
 U.S. Naval Academy 6–15
 Background 6–15
 Assessment 6–15
 Planting 6–15

**APP A: SAV ACTIVITIES AT DOD
 INSTALLATIONS ON THE CHESAPEAKE BAY
 AND ITS TIDAL TRIBUTARIES A–1**

**APP B: TECHNICAL POINTS OF CONTACT FOR
 SAV IN THE CHESAPEAKE BAY B–1**

APP C: EQUIPMENT AND SUPPLIERS	C-1
APP D: SAMPLE SAV SURVEY FORM	D-1
APP E: GROUNDTRUTHING PROTOCOL	E-1
APP F: SAMPLE PURCHASE ORDER	F-1
APP G: WATER QUALITY SAMPLING PROTOCOL	G-1
APP H: FIELD WATER MONITORING DATA SHEET	H-1
APP I: WATER SAMPLE PREPARATION AND FILTERING PROTOCOLS	I-1
APP J: RESOURCES FOR SAV RESTORATION, FUNDING, AND PARTNERING	J-1
APP K: SAV FLOAT AND TANK CONSTRUCTION	K-1
REFERENCES	R-1

EXHIBITS

1-1. Common Species of SAV in the Chesapeake Bay and Its Tributaries	1-2
1-2. Why SAV Is Important.	1-4
2-1. Optimal Conditions for SAV Aerial Mapping and Photography	2-6
2-2. Groundtruthing Equipment List.	2-8
3-1. Water Quality Parameters Affecting SAV Growth	3-15
3-2. Selecting Monitoring Sites.	3-20
3-3. Recommended Analytical Laboratories in Chesapeake Bay Region	3-25
4-1. Required Elements of an SAV Restoration Plan	4-2
4-2. Functional Groups of SAV and Their Representative Species	4-8
C-1. Field Equipment Suppliers	C-2
C-2. Plant Stock and Seed Distributors.	C-4
D-1. SAV Species Abbreviations.	D-1
J-1. Organizations with SAV Restoration Resources	J-2
J-2. Funding Sources and Partnership Opportunities	J-3
J-3. Additional SAV Information	J-4

FIGURES

1-1. Sediments, nutrients, and epiphytic growth can affect the amount of sunlight reaching plants	1-6
1-2. SAV cover in the Chesapeake Bay from 1984 to 2003	1-9
2-1. Example of SAV distribution quadrangle map	2-10
3-1. Calculation of PLW and PLL and comparisons with their respective light requirements	3-17
4-1. Flow chart for SAV species selection based on environmental conditions	4-6
4-2. Researchers installing SAV floats	4-10
4-3. Planning the restoration effort based on planting area, methods, propagules, and budgetary constraints	4-12
4-4. Types of propagules available for restoration efforts: tubers and bare-root	4-13
4-5. Various SAV restoration efforts around the Chesapeake Bay	4-14
4-6. Outdoor SAV tanks at CB-NERR's Otter Point Creek Reserve	4-22
5-1. MD-DNR staff members with schoolchildren in "Grasses for the Classes" planting projects	5-5
5-2. Volunteer displays <i>V. americana</i> plants	5-7
6-1. TSS, DIN, DIP, and light attenuation as indicators of water quality at station L1 near Langley Air Force Base	6-4
6-2. SAV planting and harvesting sites at Langley Air Force Base	6-6
6-3. Eelgrass arrangement for the horizontal rhizome method of planting	6-7
6-4. Planting grid design at Langley Air Force Base	6-8
6-5. TSS, DIN, and DIP concentrations at station IH2 near Indian Head Naval Warfare Center	6-10
6-6. Planting design at Indian Head Naval Warfare Center	6-12
6-7. Planter and divers adjust a planting grid	6-13
6-8. Volunteers building an enclosure fence	6-13
6-9. U.S. Naval Academy SAV planting site	6-16
6-10. TSS concentrations for the four sites at the U.S. Naval Academy	6-17
K-1. Construction phase of an outdoor SAV tank	K-4

TABLES

1-1. Recommended habitat requirements for SAV growth and survival in Chesapeake Bay and tidal tributaries	1-7
2-1. Examples of species-specific variation in peak biomass	2-12
3-1. Physical and chemical habitat characteristics affecting the growth or occurrence of various kinds of SAV	3-3
3-2. Reproductive strategies of selected SAV species in the Chesapeake Bay	3-10
3-3. Suggested sampling designs for different monitoring goals.	3-24

Acronyms and Abbreviations

ACB	Alliance for the Chesapeake Bay	ft	foot
APG	Aberdeen Proving Ground	GIS	geographic information system
cm	centimeter	GPS	global positioning system
cm s ⁻¹	centimeters per second	in	inch
CBF	Chesapeake Bay Foundation	K _d	light attenuation coefficient
CB-NERR	Chesapeake Bay National Estuarine Research Reserve	L	liter
Chl-a	chlorophyll-a	lb	pound
CBL	Chesapeake Biological Laboratory	MD-DNR	Maryland Department of Natural Resources
CBP	Chesapeake Bay Program	m	meter
DIN	dissolved inorganic nitrogen	m ²	square meter
DIP	dissolved inorganic phosphorus	µg L ⁻¹	micrograms per liter
DO	dissolved oxygen	mg L ⁻¹	milligrams per liter
DOD	Department of Defense	mL	milliliter
DSHE	Directorate of Safety, Health, and the Environment	mm	millimeter
EPA	Environmental Protection Agency	mM	millimoles
		N	nitrogen

NAIB	National Aquarium in Baltimore	TP	total phosphorus
P	phosphorus	TSS	total suspended solids
PAR	photosynthetically active radiation	TVS	total volatile solids
PLL	percent light at leaf	UMCES	University of Maryland Center for Environmental Science
PLW	percent light through water	USAEC	United States Army Environmental Center
PO	purchase order	USDA	United States Department of Agriculture
PPT	parts per thousand	USGS	United States Geological Survey
PVC	polyvinyl chloride	VIMS	Virginia Institute of Marine Science
QA/QC	quality assurance/quality control	VMRC	Virginia Marine Resource Commission
SAV	submerged aquatic vegetation	WAAS	Wide Area Augmentation System
SCUBA	self-contained underwater breathing apparatus		
TN	total nitrogen		

Foreword

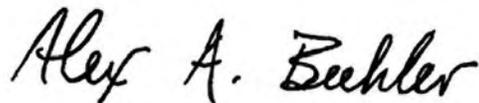
The Department of Defense (DOD) is committed to protecting and enhancing biodiversity on the lands and waters it manages, including those in the Chesapeake Bay Watershed. The Chesapeake Bay is of great importance to DOD, strategically and environmentally. The Chesapeake Bay region has long provided the waters, sandy shores, and forested buffers necessary to carry out the DOD training mission and to improve the quality of life for soldiers and their families. The DOD recognizes the unique assets of the Bay and is committed to its restoration and enhancement. Throughout the Bay watershed, from the Pentagon to each of the 66 military installations located there, the DOD employs scientists and resource managers dedicated to researching, safeguarding, restoring, and enhancing the Bay and its resources.

One important component of the DOD's multifaceted Chesapeake Bay Program involves researching and restoring submerged aquatic vegetation (SAV). Our



military natural resource managers recognize the important role that these underwater plants play in the Bay's overall health. For those installations within the historic range of SAV in the Chesapeake Bay, the DOD has been able to make significant contributions to understanding and managing this important resource. Chapter 6 of this handbook, Case Studies, details three of the many SAV restoration projects initiated by the DOD.

This handbook is the product of years of DOD involvement with SAV and of the valuable partnerships with the greater scientific community forged along the way. These combined efforts ensure that natural resource management is integrated with military readiness activities and strengthen the DOD's reputation as a good environmental steward. We have the best-trained military force in the world, while continuing to be a world leader in environmental management and conservation of our natural resources. It is our hope that resource managers everywhere will find this handbook to be a valuable tool in their own restoration efforts.

A handwritten signature in black ink that reads "Alex A. Beehler". The signature is written in a cursive, flowing style.

—*Alex A. Beehler*
Assistant Deputy Under Secretary of Defense
(Environment, Safety and Occupational Health)

Preface

At least 14 projects related to submerged aquatic vegetation (SAV) have been undertaken at Department of Defense (DOD) installations or facilities in the Chesapeake Bay. Nine DOD projects involved attempts to restore or plant SAV, with varied outcomes and degrees of success. Unfortunately, the relative success of these efforts has been difficult to evaluate, in part because of varying levels of commitment, the use of different sampling designs and protocols, or inadequate post-restoration monitoring.

This handbook presents a standardized approach and accepted protocols for conducting an SAV restoration program on DOD installations. Applying the methods and protocols described in the handbook can minimize future duplication of effort, repetition of past mistakes, and promote information exchange among DOD installations and the scientific community. Additionally, the guidelines contained in the following chapters will provide a basis for modifying existing programs to adapt to changing science and will encourage the use of new designs and techniques in SAV research and restoration.

While this handbook summarizes the current state of the art and science of SAV restoration, the field is relatively young and there is much to be learned. Even unsuccessful projects can make important contributions to the field of SAV restoration if they are planned, conducted, and documented in a systematic manner. Conducting your SAV restoration program in accordance with this handbook will not guarantee success. However, doing so will increase your odds of success and will provide the greatest value to your program, installation, and other managers and scientists throughout the region. Although the handbook is written for use on DOD installations, the information should be useful to other organizations and agencies as well.

Chapter 1 contains a brief review of relevant background information on SAV and describes a model SAV restoration program. The remainder of the handbook is devoted to planning and implementing that model program. The model is a comprehensive approach to SAV restoration that consists of initial SAV surveys (chapter 2), evaluation of habitat and water quality (chapter 3), restoration techniques (chapter 4), and education and outreach initiatives (chapter 5). Chapter 6 presents three case studies of SAV restoration projects undertaken at DOD installations on the Chesapeake Bay. Numerous appendixes present information on important points of contact, field equipment, sampling protocols, and other topics.

Acknowledgments

The U.S. Army Environmental Center and the Department of Defense Legacy Resource Management Program generously provided funding for this project. The handbook was developed with the guidance and support of Rosemary Queen and Janmichael Graine of the U.S. Army Environmental Center.

Horne Engineering Services, Inc., produced this handbook with support from the Chesapeake Research Consortium. The following individuals contributed their technical expertise to various portions of the handbook:

- Julie Bortz, Chesapeake Bay National Estuarine Reserve, Maryland Department of Natural Resources
- Dr. Katia Engelhardt, Appalachian Laboratory, University of Maryland Center for Environmental Science
- Dr. Evamaria Koch, Horn Point Laboratory, University of Maryland Center for Environmental Science
- Bob Murphy, Alliance for the Chesapeake Bay
- Dr. Kevin Sellner, Chesapeake Research Consortium
- Rebecca Thur, Chesapeake Research Consortium
- Karen Yee, University of Calgary, formerly with the Chesapeake Research Consortium.

The following individuals from Horne Engineering contributed to the development and production of the handbook:

- Shana Bullock
- Gina Kvitkovich
- Helene Merkel
- Amanda Peyton
- Owen Shifflett
- Mark Zimmerman.

To develop the chapter on Case Studies, the following DoD natural resources personnel graciously provided information on SAV projects undertaken at Chesapeake Bay installations:

- Dr. James Bailey, Aberdeen Proving Ground
- Lisa Billow, formerly Navy Region Mid-Atlantic, Little Creek
- Jeff Bossart, Naval District Washington, Indian Head
- John Bowman, Fort Myer Military Community
- Mark Dickerson, Bolling Air Force Base
- Patsy Kerr, Commander Navy Region Mid-Atlantic, formerly of Langley Air Force Base
- Glenn Markwith, formerly Commander Navy Region Mid-Atlantic
- Terry Sanders, Fort Eustis
- Aileen Smith, formerly Navy Region Mid-Atlantic
- Jacqueline Smith, Naval Air Station, Patuxent River
- Steve Wampler, Aberdeen Proving Ground
- Bob Wardwell, Adelphi Research Laboratory and Blossom Point Field Test Facility

- 
- Grady Wesson, Fort Monroe
 - Charlie Wilson, Navy Region Mid-Atlantic, Yorktown
 - Dr. Thomas Wray, Naval District Washington, Dahlgren
 - Tommy Wright, NAVFAC, Washington.

The authors also appreciate the meaningful review comments received from the following individuals:

- Todd Beser, Oak Ridge Institute for Science and Education Environmental Management Program fellow at the U.S. Army Environmental Center
- Bruce Estrella, Massachusetts Division of Marine Fisheries
- John Housein, Oak Ridge Institute for Science and Education Environmental Management Program fellow at the U.S. Army Environmental Center
- Patsy Kerr, Commander Navy Region Mid-Atlantic, formerly of Langley Air Force Base
- Sarah Martin, U.S. Army Installation Management Agency, Northeast Region Office
- Mary Shively, U.S. Army Installation Management Agency, Northeast Region Office
- Bob Wardwell, U.S. Army Adelphi Laboratory Center
- Grady Wesson, Fort Monroe.

Scientific Terms

Bayscaping – An environmentally sound approach to creating and managing lawns, gardens, and other natural landscapes that most closely resemble and function like historical natural areas of the Chesapeake Bay watershed. (See <http://www.acb-online.org/project.cfm?vid=85> for more information and access to instructional materials.)

Biomass – The total mass of all the organisms of a given type or in a given area.

Biotic – Living components of the environment.

Bioturbation – Disruption of the benthic habitat by bottom-living animals; often involves digging and shuffling, ingestion of material, and burrowing.

Chlorophyll-a (chl-a) – A measurable pigment within phytoplankton that is often used as a proxy for expressing algal biomass or nutrient concentrations present in a water column.

Clone – A genetically identical copy of another organism, generated by asexual reproduction or through propagation of bulbs or cuttings.

Conductivity – A measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved

solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). As the concentration of salts in the water increases, electrical conductivity rises; the greater the salinity, the higher the conductivity. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is extrapolated to a standard temperature (25 °C).

Detection limits – The lowest concentrations of a given substance that an analytical method or equipment can detect and still report as greater than zero. Generally, as readings approach the detection limit (that is, as they go from higher, easier-to-detect concentrations to lower, harder-to-detect concentrations), the readings become less and less reliable.

Detritus – Fragments of dead plants or animals in the process of decay; a major food source for many animals.

Dissolved inorganic nitrogen (DIN) – Nitrogen from nonliving sources that has passed into solution.

Dissolved inorganic phosphorous (DIP) – Phosphorous from nonliving sources that has passed into solution.

Epiphytes – Small-to-medium-size nonparasitic plants and invertebrates that grow on and foul SAV leaves.

Eutrophication – Elevated levels of nutrients (especially nitrogen and phosphorous) in the water column.

Exclosure – A structure built around newly planted SAV beds or seeded areas to protect them from grazing pressure or tidal currents before the SAV has had a chance to become established.

Fouling – Epiphytic growth that builds up on SAV leaves or exclosures, restricting water exchange or reducing light penetration. Lower-flow areas are particularly susceptible to rapid fouling.

Groundtruthing – The process of conducting ground surveys to verify the presence of SAV beds, identify SAV species, and locate smaller beds that may not have been captured by aerial photography.

Infauna – Sessile and mobile animals that spend part or all of their lives buried in deposited matter on the sea floor.

Intertidal – The area of a shoreline or tidal wetland between mean high and mean low tides; also called the littoral zone.

Light attenuation coefficient (K_d) – A quantification of light intensity reduction caused by absorption and scattering that takes into account water properties, sun angle, sky conditions, depth, and shadowing.

Mesohaline – Pertaining to moderately brackish water with a salinity of 5 to 18 ppt.

Metadata – “Data about data.” Information that helps characterize the data collected. Metadata answer who, what, when, where, why, and how about every facet of the data being documented. This information helps others understand exactly how the data was obtained.

Micropropagation – The process of plant multiplication in vitro, that is, growing plants from seed or small pieces of tissue under sterile conditions in a laboratory on specially selected media; also known as tissue culture.

Oligohaline – Pertaining to slightly brackish water with a salinity of 0.5 to 5 ppt.

PAR – Photosynthetically active radiation; the portion of the sunlight spectrum that plants use for photosynthesis.

Peat – Partially carbonized, acidic organic material formed by partial decomposition in water of various plants.

Percent light at leaf (PLL) – A measure of the percentage of surface light available at the SAV leaf surface; accounts for light attenuation by epiphytes and periphyton on the leaf surface, in addition to attenuation that occurs through the water column.

Percent light through water (PLW) – A measure of the percentage of surface light available in the water directly overlying the SAV leaves; accounts for light attenuation through the water column by phytoplankton, suspended particles, and water color.

Periphyton – A broad assemblage of algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates that grows on submerged surfaces, such as SAV leaves.

pH – A measure of the alkalinity or acidity of a substance; the pH is neutral at 7.0, acidic below 7.0, and alkaline above 7.0.

Phytoplankton – Microscopic algae that are suspended in the water column.

Plankton chlorophyll-a (chl-a) – A measure of algal biomass used to indicate nutrient concentrations in a water column.

Polyhaline – Pertaining to highly brackish water with a salinity of >18 ppt.

Porewater – Water in openings or spaces in rocks, soil, or sediment (also known as pore water).

Propagation – The process of increasing in number.

Propagules – A structure with the capacity to give rise to a new plant, that is, a seed, a spore, or a part of the vegetative body capable of independent growth if detached from the parent.

Rhizomes – In perennial plants, the underground stem, usually horizontal, that produces aerial shoots.

Salinity – The measurement of dissolved salts in water; the number of grams of dissolved salts in 1,000 grams of water.

Secchi depth – The depth at which the Secchi disk, when lowered into the water, can just barely be seen (without sunglasses and on the sunny side of the boat or dock). A Secchi disk is an 8-inch disk with alternating black and white quadrants. Secchi depth is a measure of the transparency of water and can be used to calculate light attenuation (K_d) and ultimately the percent light through water (PLW).

Substrate – The bottom surface of a body of water on or in which benthic organisms dwell.

Tidal – Describes a body of water influenced by tides, the regular rise and fall of the water level in the earth's oceans because of gravitational forces between the earth, moon, and sun.

Tidal fresh – Pertaining to water with a salinity of less than 0.5 ppt that is influenced by tides.

Total suspended solids (TSS) – Particles in the water column, consisting of inorganic solids (silts and clays) and organic detritus, that contribute to light scattering and attenuation; often referred to as turbidity.

Trophic level – A food-producing or feeding level along a food chain (for example, producer [plant], herbivore, carnivore, and so forth).

WHAT IS SAV

Submerged aquatic vegetation (SAV) is a group of true, flowering plants adapted to living and reproducing underwater. SAV is also known locally as “bay grass,” and SAV that grows strictly in marine environments is often called “seagrass,” although all species of SAV are in fact more closely related to water lilies than to terrestrial grasses. SAV occurs throughout the Chesapeake Bay in areas ranging in **salinity** from freshwater (0 to 5 parts per thousand (ppt)) to saltwater (>30 ppt), with the greatest diversity of species occurring in **tidal fresh** (<0.5 ppt) and **oligohaline** (0.5 to 5.0 ppt) salinity regimes.

Unlike mosses or algae, SAV species reproduce sexually through flowers, pollination, and subsequent seed dispersal, although many species also reproduce asexually. Most SAV species have true roots that anchor the plants to and take up nutrients from the sediment. SAV also has unique characteristics that support survival and growth in aqueous environments. These include —

- Long, slender leaves and flexible stems that allow plants to move with the currents and waves without being dislodged (for example, *Vallisneria americana* (wild celery))

- Thin leaves that enhance a plant's ability to extract nutrients from the water column (for example, *Potamogeton perfoliatus* (redhead grass))
- In some cases, floating leaves that can take up atmospheric carbon dioxide (for example, *Potamogeton nodosus* (American pondweed)).

Fifteen species of SAV, including several nonnative species, are commonly found in the Bay and its tributaries (exhibit 1-1).

Exhibit 1-1. Common Species of SAV in the Chesapeake Bay and Its Tributaries

<i>Callitriche</i> spp. (water starworts)	<i>Potamogeton crispus</i> (curly pondweed)
<i>Ceratophyllum demersum</i> (coontail)	<i>P. pusillus</i> (slender pondweed)
<i>Elodea canadensis</i> (American waterweed)	<i>P. perfoliatus</i> (redhead grass)
<i>Heteranthera dubia</i> (water stargrass)	<i>Ruppia maritima</i> (widgeon grass)
<i>Hydrilla verticillata</i> (hydrilla ¹)	<i>Stuckenia pectinata</i> (sago pondweed)
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil ¹)	<i>Vallisneria americana</i> (wild celery)
<i>Najas</i> spp. (naiads ²)	<i>Zannichellia palustris</i> (horned pondweed)
	<i>Zostera marina</i> (eelgrass)

¹Nonnative, invasive species.

²Some naiads, such as *N. minor*, are also nonnative species.

FACTORS THAT INFLUENCE SAV DISTRIBUTION AND GROWTH

SAV serves many valuable functions within estuarine ecosystems (exhibit 1–2). In freshwater, tidal fresh, and oligohaline waters, SAV can act as an early line of defense, intercepting and filtering nutrients and trapping sediments before they can reach and impact more saline areas. Without this buffer, excessive nutrients can lead to algal blooms, anoxia, and **epiphyte** growth on halotolerant SAV species. In addition, because of its strong dependence on good water quality and clarity for successful growth and reproduction, SAV abundance and diversity are good indicators of the general health of the Chesapeake Bay.

It is crucial to understand the environmental factors that promote or limit SAV growth when designing a SAV restoration program. Salinity levels broadly govern which species of SAV can grow in an area. Within a particular salinity regime, the percent of sunlight that reaches the plants' leaves is the primary habitat requirement that determines SAV growth and survival. This percentage is called the **percent light at leaf** (PLL). The PLL is a function of light attenuation in the water column and attenuation of light through the epiphyte (conglomerate of algae, bacteria, and debris) layer on the leaves of the plant. A lack of sufficient light, often because of high sediment loading or excessive nutrient input gone unchecked, is often the reason that SAV restoration efforts fail.

A suite of water quality parameters affects the amount of light transmitted through the water column. Increasing concentrations of **total suspended solids** (TSS), **plankton chlorophyll-a** (chl-a), **dissolved inorganic nitrogen** (DIN), and

Exhibit 1-2. Why SAV Is Important

Monitoring and restoring SAV is a key element in the multijurisdictional effort to restore the Chesapeake Bay. SAV is important to the overall Bay restoration effort because of the various roles it plays in the Bay ecosystem, including the following:

- ❑ Provides nursery habitat, food, and shelter for juvenile fish, blue crabs, and other commercially and ecologically important species
- ❑ Serves as a vital food source for resident and migratory waterfowl, some endangered, that consume both its vegetative material and seeds
- ❑ Enhances water clarity by buffering shorelines, reducing sediment resuspension, and trapping suspended particles
- ❑ Reduces erosion by stabilizing the sediment with its roots and rhizomes
- ❑ Improves water quality by removing toxins and nutrients, such as nitrogen and phosphorus, from the water column
- ❑ Produces detritus as it decomposes, which serves as a valuable food source for zooplankton, thereby contributing to energy transfer up the food chain
- ❑ Oxygenates the surrounding water column, enhancing water quality for other aquatic organisms.



dissolved inorganic phosphorus (DIP) reduce the amount of light available for SAV. For example, when nutrient concentrations increase (a process called **eutrophication**), **phytoplankton** and epiphytes grow faster and more densely, reducing light levels at the SAV leaf surfaces (see figure 1–1). Research on light, water quality, and SAV has led to the establishment of minimum habitat requirements for growth and survival of SAV under different salinity regimes in the Chesapeake Bay and its **tidal** tributaries (table 1–1).

SAV distribution and growth are also strongly affected by physical habitat characteristics, including water depth, wave exposure, and sediment type, and by **biotic** characteristics, such as competition from invasive, nonnative SAV species (the effects of these are detailed in chapter 3). In some cases or in particular years, SAV has also been reduced or even locally eliminated by grazing animals, the use of particular fishing gears, and local or regional storm events. During “wet years,” such as 2003, runoff from land can contribute to elevated nutrient and suspended sediment levels and subsequent reductions in SAV abundance. In contrast, during “dry years,” such as 2002, nutrient and suspended sediment levels in the water column are usually reduced. Consequently, SAV abundance is high. While SAV tends to recover from short-lived disturbances, such as storms or overgrazing, prolonged or chronic disturbances associated with disease and eutrophication can render an area barren indefinitely.

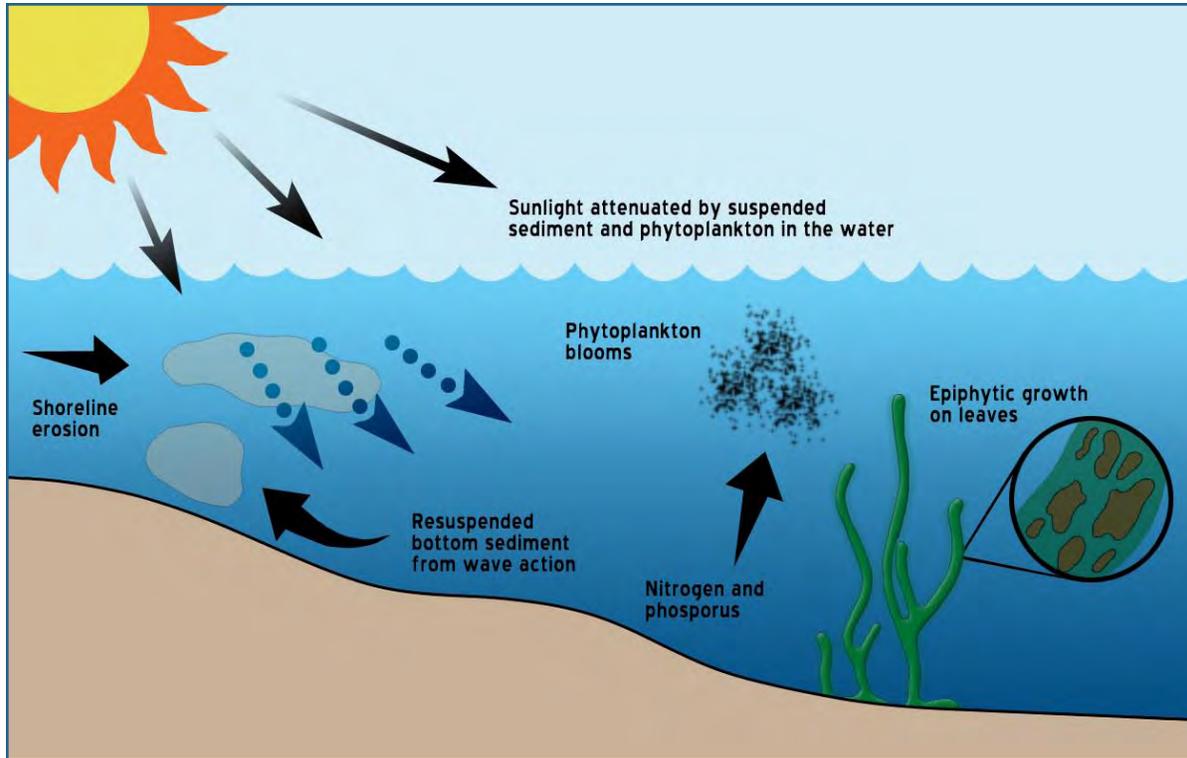


Figure 1-1. Sediments, nutrients (and accompanying algal blooms), and epiphytic growth can ultimately affect the amount of sunlight reaching plants. SOURCE: U.S. EPA COASTAL PROTECTION BRANCH 1993

Table 1–1. Recommended habitat requirements for SAV growth and survival in Chesapeake Bay and tidal tributaries

Salinity regime ¹	SAV growing season ²	Primary requirement ³	Secondary requirements ⁴				
		Minimum light requirement (%)	Water-column light requirement (%)	TSS (mg L ⁻¹)	Chl-a (µg L ⁻¹)	DIN (mg L ⁻¹)	DIP (mg L ⁻¹)
Tidal fresh	April–Oct.	>9	>13	<15	<15	—	<0.02
Oligohaline	April–Oct.	>9	>13	<15	<15	—	<0.02
Mesohaline	April–Oct.	>15	>22	<15	<15	<0.15	<0.01
Polyhaline	March–May, Sept.–Nov.	>15	<22	<15	<15	<0.15	<0.02

Note: mg L⁻¹ = milligrams per liter; µg L⁻¹ = micrograms per liter.

¹ Regions of the estuary defined by salinity regime, where tidal fresh = <0.5 ppt, oligohaline = 0.5 to 5 ppt, **mesohaline** = 5 to 18 ppt, and **polyhaline** = >18 ppt.

² Medians calculated over this growing season should be used to check the attainment of any of these habitat requirements, and raw data collected over this period should be used for statistical tests of attainment. For polyhaline areas, the data are combined for the two growing season periods shown.

³ Minimum light requirements for SAV survival based on analysis of literature, evaluation of monitoring and research findings, and application of models. Use the primary requirement, or minimum light requirement, whenever data are available to calculate PLL (this requires measurements of **light attenuation coefficient** [K_d] or **Secchi depth**, TSS, DIN, and DIP).

⁴ Relationships were derived from statistical analyses of field observations on water quality variables in comparison to SAV distributions at selected sites. The secondary requirements are diagnostic tools used to determine possible reasons for nonattainment of the primary requirement (minimum light requirement). The water-column light requirement can be used as a substitute for the minimum light requirement when data required to calculate PLL are not fully available.

Source: Batiuk et al. 2000.

SAV ABUNDANCE – A HISTORICAL PERSPECTIVE

Historically, close to 200,000 acres of SAV once grew in the Chesapeake Bay. However, by 1984, aerial surveys of SAV documented only 38,000 acres (Orth and Moore 1983; 1984). Though a partial SAV recovery has been observed over the last 20 years (figure 1–2), some of the same factors that contributed to its dramatic Baywide decline in the late 1960s and early 1970s continue to stall further progress. Among these are anthropogenic inputs (for example, nutrient, sediments, and pollutants) related to development in the watershed and natural phenomena (for example, invasive species competition and hurricanes).

In the early 1930s, the entire Atlantic range of eelgrass, *Zostera marina*, was stricken with disease. This “wasting disease,” as it is commonly known, was responsible for a 90% decline in eelgrass abundance. Though most beds began reestablishing themselves by the 1940s, some areas failed to recover and other mounting pressures soon took their toll on Bay grasses as a whole. Invasive species, such as water chestnut (*Trapa natans*), Eurasian watermilfoil (*Myriophyllum spicatum*), and hydrilla (*Hydrilla verticillata*) appeared in the 1940s, late 1950s to early 1960s, and 1980s, respectively. Each of these nonnative species disrupted the Bay by temporarily and sometimes permanently displacing many native SAV species or choking waterways. Hurricane Agnes in June 1972 caused extensive Baywide damage to SAV beds when its heavy rainfall lowered salinity and greatly increased turbidity. The effects of Hurricane Isabel in September 2003 on SAV were not as severe because of its occurrence toward the end of the growing season and the significantly lower amount of

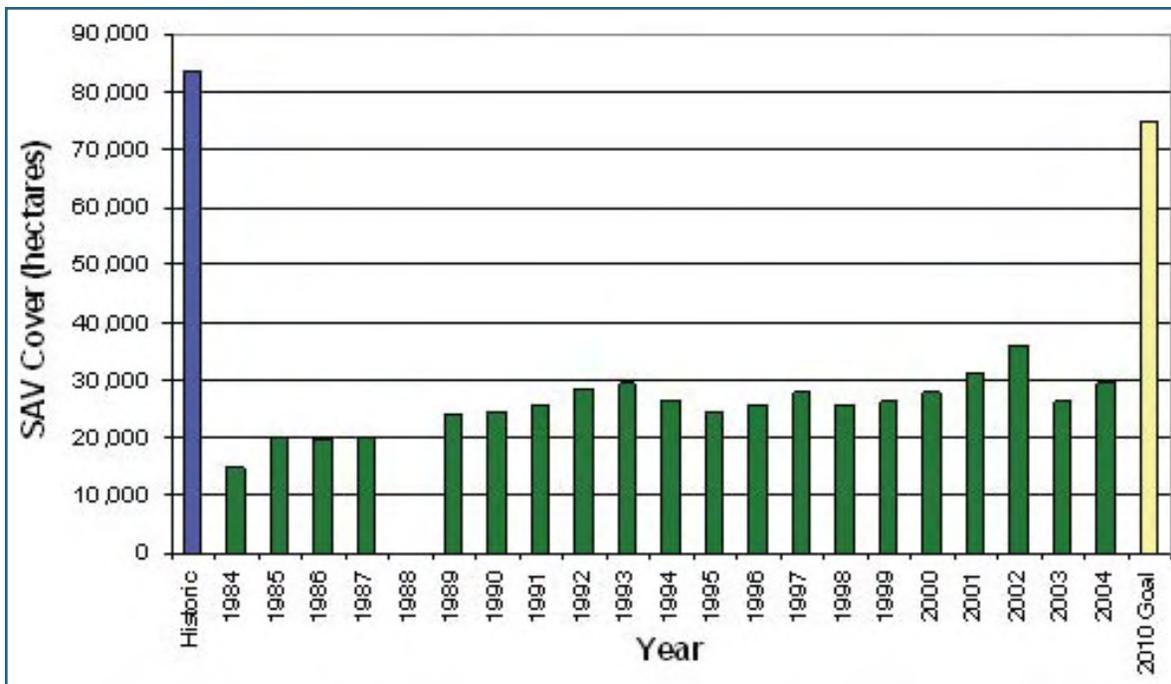


Figure 1–2. SAV cover in the Chesapeake Bay from 1984 to 2004. The bar labeled “Historic” represents a composite of maximum Baywide SAV coverage experienced from the 1930s to 1971. Note the recovery period observed from 1984 to 1993, following efforts to improve water quality. There were 29,516 hectares (72,935 acres) of SAV detected by aerial surveys in 2004. A 2010 restoration goal of approximately 75,000 hectares (185,000 acres) was established by the Chesapeake Bay Program in 2003. SOURCE:

CHESAPEAKE BAY PROGRAM

EFFORTS TO RESTORE SAV

rainfall associated with the storm. Overall, the wet year of 2003 may have had more of a detrimental impact on SAV coverage than the actual hurricane.

Human activities continue to pose the greatest threat to SAV and overall Bay health. The human population in the Bay watershed grew from 5 million in 1900 to about 8 million in 1950 and exceeded 15 million by 2000 (STAC 2003). During the same period, the percentage of land devoted to agricultural land use fell from 85% in 1850 to only 28.5% in 1994, while urban and suburban development rose proportionally. Anthropogenic inputs to the Bay have risen correspondingly over time, largely because of increases in impervious surface area, septic tank installations, and overuse of commercial fertilizers. All of these have been major contributors to eutrophication and the subsequent loss of SAV (Short et al. 1996). Fortunately, modernization of sewage treatment regimes, stream bank stabilization, *Bayscaping*, and other indirect restoration methods can naturally promote SAV recovery in previously barren areas. Therefore, watershed-scale habitat rehabilitation activities other than direct SAV planting or seed casting may be necessary or helpful to ensuring restoration success.

Since 1983, the Environmental Protection Agency's (EPA) Chesapeake Bay Program (CBP) has worked toward restoring the Bay's water quality and living resources, including SAV. Nutrient loading to the Bay has gradually been reduced, and the total acres of SAV increased from a record low of 38,000



acres in 1984 to 69,000 acres in 2000. Most of this recovery occurred through natural recruitment. The CBP's new goal is to achieve 185,000 acres of SAV by 2010 through a combination of SAV restoration and continued improvements to water quality. Modernization of wastewater treatment plants, shoreline stabilization, Bayscaping, and other habitat restoration strategies are currently being pursued throughout the watershed to improve Bay water quality. Collectively, these activities are expected to naturally promote SAV recovery in previously barren areas.

The Department of Defense (DOD) is one of the largest federal landholders in the Chesapeake Bay watershed, managing nearly 400,000 acres on 66 installations. On September 13, 1984, the DOD became the first federal agency to formally involve itself with Bay restoration by signing a joint resolution with the EPA on pollution abatement in the Bay. Subsequent agreements have incorporated the latest CBP goals and paved the way for increased communication and cooperation among DOD, the CBP signatory states, and their partners. DOD installations are currently helping the CBP meet its commitment to restore 185,000 acres of SAV by 2010 through a combination of SAV mapping, monitoring, and planting programs (appendix A). This handbook will help DOD natural resource managers contribute to that commitment by providing a model SAV restoration program.

A MODEL SAV PROGRAM

Though it is impossible to ensure success in all cases, a model SAV program is a restoration effort that is planned, coordinated, implemented, and documented consistently and systematically. It incorporates a comprehensive project design and approach that will ensure that restoration decisions are supported by good science. A comprehensive SAV program consists of four components:

- SAV surveys and **groundtruthing**
- Habitat evaluation, including monitoring water quality
- Restoration, including post-restoration monitoring
- Education and outreach.

The first two components are necessary to select restoration sites capable of supporting SAV and to design a site-specific restoration project. The third component typically involves planting SAV at restoration sites. However, restoration can include activities other than planting, such as SAV **propagation**, habitat and water quality improvements, and invasive species control. Finally, some level of education and outreach should be included in every SAV program. Education can change public behaviors that have direct consequences on water quality, aquatic habitats, and SAV. An outreach program engages others in your program and makes your results available to the larger restoration community.

Each of the four model components is detailed in chapters 2 through 5. It is not necessary or even appropriate in some cases to incorporate all of the elements



associated with each component into your program. However, you should consider each element as part of a systematic and comprehensive planning process. The guidelines and recommendations in each chapter will help you plan and implement a program that meets your particular goals and available resources.

CHAPTER TWO

SAV Surveys and Groundtruthing

Before you define the specific details of your SAV restoration or monitoring program, it is vital to complete a survey of the SAV, past and present, within the area of concern. Establishing the past and present distribution and density of SAV, including species composition, will help determine an area's potential for restoration and will establish baseline data with which to compare future changes in SAV distribution and density.

Note that consistently unvegetated areas are typically unsuitable for restoration even though SAV may be present in adjacent areas. Unvegetated areas often indicate environmental conditions that limit SAV growth (for example, strong currents or a rocky bottom) or are affected by land-based disturbances (for example, erosion or pollution). In the latter case, attention might be better directed towards land-based remediation before any SAV propagation is attempted.

Historic records of SAV distribution will reveal sites that once supported SAV and therefore may be likely to support regrowth if water quality conditions are suitable. Finding or developing maps of historical SAV distribution of a

HISTORIC
DISTRIBUTION OF SAV

potential restoration site can be time-consuming. However, at a minimum, the most recent historical distribution (that is, 1984 to present) should be examined before selecting possible restoration sites.

Various options or sources are available to determine the historic distribution of SAV in the Chesapeake Bay. Perhaps the best and easiest option is to examine the historical SAV distribution data compiled by the Virginia Institute of Marine Sciences (VIMS). Since 1984, VIMS has documented annual changes in SAV distribution throughout the Chesapeake Bay with aerial photographs taken from fixed-wing aircraft. From black-and-white aerial photographs flown at a scale of 1:24,000, SAV beds are identified and their boundaries traced onto U.S. Geological Survey (USGS) quadrangles and digitized into a geographic information system (GIS) database. Additionally, each area or bed of SAV is classified into one of four density classes that show the percentage of SAV cover as interpreted from the aerial photographs (Orth et al. 2002).

Data collected by VIMS has been used to produce annual reports of SAV distribution and abundance. Reports from 1994 to present are available on the VIMS Web site (<http://www.vims.edu/bio/sav/index.html>). Hard copies of reports from 1984 to 1993 can be obtained by contacting VIMS directly (see Dr. Robert Orth, appendix B).

Information on SAV distribution before 1984 is scarce. The information that is available includes the following regions and years:

- Western shore, Virginia only – 1971 and 1974
- Lower Bay, Virginia only – 1980 and 1981
- Upper Bay, selected sections – 1979
- Baywide – 1978 only.

Aerial photographs predating 1971 were taken by the U.S. Department of Agriculture (USDA) Soil Conservation Service (now known as the Natural Resource Conservation Service). However, the purpose of the photography was not to document SAV. Consequently, only the photograph sets from 1938, 1952, 1957, and 1964 were flown under the correct conditions (time of year, water clarity, and scale) for detecting SAV distributions. The Maryland Department of Natural Resources (MD-DNR) has analyzed those sets and archived the historic SAV distribution for most Maryland waters in a GIS database (see Mike Naylor, appendix B). Similar information is available for Virginia's tidal waters (see Dr. Ken Moore, appendix B).

Examining old photographs for location and approximate distribution of historic beds can also be used to evaluate potential restoration sites. Both the Maryland Geological Survey archive in Baltimore and the National Archives in Washington, D.C., contain historic photographs that can be examined on-site or purchased as duplicates. Finally, DOD resource managers should check with their installation's security office, public affairs, and GIS support staff to see if aerial photographs were taken of their installations for training requirements,

CURRENT DISTRIBUTION OF SAV

planning, or other purposes. Be aware, however, that some photographs that might appear to be suitable (such as an aerial view of the coastline) may not upon examination yield much information about SAV conditions because the images were not taken under the right conditions.

After performing an archival review, a thorough current survey of the installation's tidal waters is recommended to compare current and historic distribution. The best way to survey a large area is to fly over the installation's waters. Note that if you conduct the survey from a helicopter, the prop wash may disturb the water surface and make it difficult to observe SAV. An aerial survey typically requires a fair amount of preparation and paperwork, but can be very helpful if the installation is large (more than 5,000 acres of tidal waters) or difficult to access by boat. Aerial surveys are relatively expensive, but sometimes can be arranged and provided by the installation itself at little or no cost.

From the air, dark patchy areas in the water may represent SAV beds, rocks, algae, or debris. Consequently, it is essential to include an experienced SAV observer on the survey team and to groundtruth the area at a later date. All potential SAV beds should be drawn by hand on a map as they are observed during the flight. Digital photographs and videotapes with narration are also helpful to record observations and subsequently interpret the maps.

GROUNDTRUTHING

Aerial surveys for SAV are typically conducted at the height of the growing season (mid-July to mid-September) and only under particular conditions and times of day. The optimum conditions for viewing and photographing SAV from the air are at low tide, when water clarity is high, when winds are relatively calm, and the sun is at a high angle. Exhibit 2–1 contains specific recommendations for SAV aerial mapping.

The outline of each bed is hand-drawn on a map as the beds are observed during the flight. Aerial SAV surveys are conducted most efficiently by two people: one to delineate the beds and another to record notes and take still or video photography to document the location of each bed. The photographs or videos are used to verify and interpret hand-drawn locations. Photographs should be taken perpendicular to the water's surface to minimize distortion.

If aerial access is not available, you should contact VIMS to ask about obtaining photographs or digital images of your site (see Dr. Robert Orth, appendix B). VIMS aerial SAV survey photographs from the current year are available at reasonable cost (see Air Photographics, appendix C).

When tidal waters are observed or photographed from the air, dark areas that appear to be SAV may also be attributable to microalgae, **detritus**, rocks, or even debris. Consequently, it is vital to conduct surveys at ground (or water) level to verify SAV presence and bed boundaries. Groundtruthing is the

Exhibit 2-1. Optimal Conditions for SAV Aerial Mapping and Photography

- ❑ **Atmospherics:** During periods of no or low haze or clouds below aircraft; above aircraft, no more than scattered or thin broken clouds or thin overcast to ensure maximum SAV contrast to bottom
 - ❑ **Land Features:** Flight line should include sufficient identifiable land area to ensure accurate plotting of bed
 - ❑ **Plant Growth:** When growth stages ensure maximum delineation of SAV and when species overlap is greatest
 - ❑ **Sensor Operation:** In the vertical mode with less than 5° tilt; the scale/altitude/film/focal length combination should permit resolution and identification of a 1-square-meter area of SAV (at the surface)
 - ❑ **Sun Angle:** When the angle of the sun is between 20° and 40° above the horizon, or when surface reflection from sun glint does not cover more than 30% of camera frame
 - ❑ **Tidal Stage:** At low tide, +/- 0 to 1.5 feet, as predicted by the National Oceanic and Atmospheric Administration (<http://tidesonline.noaa.gov/>)
 - ❑ **Turbidity:** When water clarity will ensure complete delineation of grass beds, as visually determined from the airplane by the SAV observer
 - **Wind:** During periods of no or low wind; when wind conditions cannot be avoided, offshore winds are preferred to onshore winds
- Source: Orth et al. 2003.



process of conducting ground surveys to verify the presence of SAV beds, identify SAV species, and locate beds that may not have been captured by aerial photography. Groundtruthing should be conducted as soon as practically possible after any aerial survey.

Groundtruthing is vital not only to verify aerial survey results, but also to identify SAV species, locate deep or low-density beds that were undetected during a flight, and record more detailed information. Groundtruthing also ensures that SAV surveys are comprehensive and include all areas that could potentially support SAV. This is particularly important when surveys are conducted as part of restoration planning.

Selecting the appropriate level of effort and protocol for groundtruthing will depend upon logistics and available resources (time, equipment, personnel, size of the area of interest), as well as the particular goals of your SAV program. At a minimum, the information to be gathered during groundtruthing should include the precise location (coordinates) and extent (dimensions or area) of all SAV beds, including those that were not detected during aerial surveys. Additional information on SAV species and depths will help you select among restoration species and sites, and can be readily accomplished while conducting the survey. Estimating SAV **biomass** or other parameters may be added to the protocol, depending upon your project or study objectives. Regardless of the scope and intent of your efforts, you should notify, plan, and share the results of any systematic SAV surveys with the personnel at VIMS who coordinate the

Groundtruthing Equipment

annual SAV surveys conducted in support of the CBP (see Dr. Robert Orth, appendix B).

Exhibit 2-2 lists the equipment and supplies needed for groundtruthing. Additional details about each piece of equipment can be found in appendix C. There are several SAV field guides available, including the *Chesapeake Bay Submerged Aquatic Vegetation Identification Guide* (David and Reel 2001),

Exhibit 2-2. Groundtruthing Equipment List

- Outboard motorboat, canoe, or kayak with required Coast Guard equipment.
- Maps
- Global Positioning System (GPS) unit or compass
- Weighted and calibrated line or calibrated measuring pole
- Secchi disk
- Measured lines or tapes
- SAV field identification guides and abbreviation list
- Sealable plastic sample bags (such as Ziploc® brand)
- Permanent marker and pencils
- Waterproof data sheets
- Clipboards
- Rakes
- Mask and snorkel or SCUBA equipment
- Footwear and clothes that can get wet, chest waders, or wet suits
- Polarized sunglasses
- View scope or underwater still or video camera
- Sunscreen and drinking water

Groundtruthing Protocol

Chesapeake Bay Foundation Guide to Underwater Grasses (http://www.cbf.org/site/DocServer/Guide_to_Underwater_Grasses.pdf?docID=116), *Field Guide to the Submerged Aquatic Vegetation of the Chesapeake Bay* (Hurley 1992), and *Underwater Grasses in Chesapeake Bay & Mid-Atlantic Coastal Waters: Guide to Identifying Submerged Aquatic Vegetation* (Bergstrom et al. 2005). In addition, the MD-DNR maintains an on-line key to Bay grasses (<http://www.dnr.state.md.us/bay/sav/key/index.asp>).

USGS quadrangle maps that include annual SAV coverage are available from VIMS (<http://www.vims.edu/bio/sav>); a portion of one is reproduced in figure 2–1. The maps display individual SAV beds labeled with a unique letter and number code (for example, A2 or B4). The letter identifies the bed, and the number indicates the density classification, which ranges from 1 (least dense) to 4 (most dense). The maps may also contain SAV species codes (appendix D) and symbols that correspond with observations appearing in the annual SAV report for that year.

Ground surveys are typically conducted at depths up to 2 meters (m), but can be extended to greater depths if warranted by extreme water clarity or observations of existing SAV (see appendix E for an example of a groundtruthing protocol).

Each survey should begin at a permanent landmark and proceed along transects in one of two patterns, depending on the bottom contours. Along shorelines with a broad, shallow shelf where SAV and potential SAV habitat are more

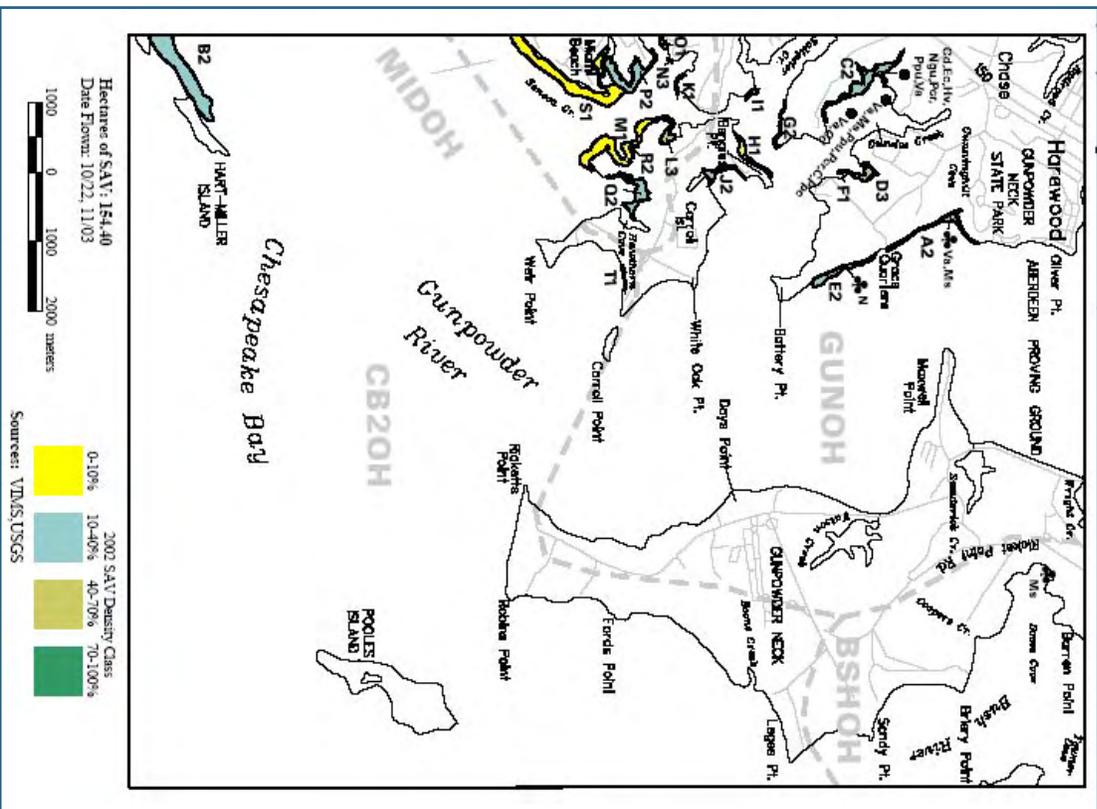


Figure 2-1. Example of SAV distribution quadrangle map. SOURCE: VMAS



uniformly distributed, proceed parallel to the shoreline on a broad zigzagging course that covers all potential SAV habitat from near-shore out to a depth of at least 2 m. Conversely, SAV distribution is likely to be patchy along shorelines where depth increases more rapidly. These areas are best surveyed by making multiple passes centered over individual depth contours. For example, survey along the 1 m (± 0.5 m) contour line. Then make a second pass along the 2 m (± 0.5 m) contour line.

A sample groundtruthing data sheet is included in appendix D. Time and water depth are recorded to correct for tidal stage, and GPS coordinates are recorded at the beginning and end of each transect and at each bed location. Observations on SAV presence, coverage (area or dimensions), bed depth, SAV density, and species composition are made using a combination of random grab samples with a rake, snorkeling, a view scope, or even underwater photography if conditions permit. Underwater videos combined with GPS technology have also been used to map SAV and seagrasses (Norris et al. 1997), but their effectiveness varies with water clarity. When visibility is poor because of depth or turbidity, the absence or presence of SAV can be detected by dragging a rake along the bottom for approximately 1 m (random rake grab) or by entering the water to snorkel or use SCUBA. Regardless of the sampling method used, documenting an absence of SAV in an area is just as important as confirming SAV presence and should be recorded on the data sheet. If no SAV is found throughout an area, always enter a zero (0) on the data sheet to indicate that the area has been surveyed.

Options for more intensive groundtruthing include determination of SAV biomass at specific or random sites throughout the installation and surveying on a seasonal basis rather than only once during peak biomass. Because random biomass sampling produces data that are difficult to interpret, it is best done along a transect from the shallowest edge of a bed to the deepest. Biomass tends to reach maximum values at mid-depth, and high SAV biomass can be an indicator of good bed health and optimal habitat. Care should also be taken not to adversely affect the health of the existing bed during sampling. Because many beds undergo seasonal fluctuations in density and distribution that cannot be captured by a onetime survey and because different species achieve peak biomass at different times of the year (table 2-1), seasonal biomass sampling results in a more complete picture of existing SAV coverage. Seasonal sampling should include early summer, midsummer, and late summer sampling intervals.

Table 2-1. Examples of species-specific variation in peak biomass

Species	Time of peak biomass	Salinity range (ppt)
<i>Z. marina</i>	March–May or September–November	10–35
<i>R. maritima</i>	Midsummer	0–35
<i>Potamogeton</i> spp.	Spring to early summer	0–5
<i>V. americana</i>	Late summer	0–10
<i>H. verticillata</i>	Late summer	0–5

CHAPTER THREE

Habitat Evaluation

In this chapter, you will learn about evaluating habitat suitability for SAV restoration: what to monitor, where to monitor, and how long and often monitoring should occur. Related topics covered include devising a standard approach to sampling, collecting data, and verifying data accuracy. You will need relevant and reliable data to select the best possible site or sites for SAV restoration.

Evaluating existing or potential SAV habitat involves measuring and observing an extremely broad set of parameters, including light availability, **substrate** type, and water movement. In the broadest sense, habitat can include innumerable variables that could affect SAV at the local, regional, and even global level. This chapter describes the main habitat characteristics that affect SAV health and growth and outlines associated sampling techniques for obtaining data that will help you assess a site's potential for supporting SAV. For organizational purposes, this handbook categorizes habitat variables into physical, biotic, and water quality parameters. However, it will readily become apparent that some parameters do not fit neatly into any organizational scheme, and these categories are certainly not exclusive.

PHYSICAL HABITAT PARAMETERS

Before considering what parameters to monitor and where to monitor them, you should account for features of the existing landscape, including relative area, adjacent land use, shoreline complexity, wave exposure, current velocity, tidal flushing, current SAV distribution, and the location of any creeks, septic tanks, storm sewers, or other point sources. Additionally, when you are planning restoration work that could be conducted over a vast area, you will benefit from the efficiency of melding a site-selection model, such as described in Short et al. (2002), with mapping and monitoring data. This strategy can help to narrow down a large set of potential sites in a streamlined fashion, though it is not a substitute for more in-depth habitat evaluation as described in this chapter and is not yet widely applicable across all SAV species.

In addition to light availability, which is the main limiting factor, the occurrence and distribution of various species of SAV may also be limited by particular variables associated with the following physical habitat characteristics (see table 3-1):

- Currents
- Waves
- Sediments
- **Porewater** chemistry.

Table 3–1. Physical and chemical habitat characteristics affecting the growth or occurrence of various kinds of SAV

Habitat Characteristic	Variable	Requirement	SAV Affected
Currents ¹	Minimum velocity (cm s ⁻¹)	0.04–5	Freshwater plants
	Maximum velocity (cm s ⁻¹)	3–16 7–50 50–180	Seagrasses Freshwater plants Seagrasses
Waves ²	Height (m)	0–1	Canopy formers (for example, <i>R. maritima</i> reproductive)
		≤2	Meadow formers (for example, <i>Z. marina</i> , <i>V. americana</i>)
Sediments ³	Grain size (% silt and clay)	2–62 0.4–30	Freshwater plants Seagrasses
	Organic matter (%)	0.4–12 <5%	Mixed species Polyhaline species
Porewater sulfide ⁴	Concentration (millimoles (mM))	<1	Healthy plants
		>1	Reduced growth
		>2	Death

Note: cm s⁻¹ = centimeters per second.

¹ Conover 1964; Westlake 1967; Sculthorpe 1967; Scoffin 1970; Phillips 1974; Fonseca et al. 1982; Madsen and Sondergaard 1983; Werner and Wise 1982; Fonseca and Kenworthy 1987; Koch 1994; Merrel 1996.

² Joanen and Glasgow 1965; Hannan 1967; Rawls 1975; Stevenson and Confer 1978; Stewart et al. 1997; Dan et al. 1998.

³ Burrell and Schubel 1977; Carter et al. 1985; Posey et al. 1993; Short et al. 1993; Edgar and Shaw 1995; Dan et al. 1998.

⁴ Pulich 1983; Carlson et al. 1994; Kuhn 1992; Goodman et al. 1995; Holmer and Bondgaard 2001; Koch and Erskine 2001.

Source: Batiuk et al. 2000, modified from Koch 2001.

Waves and Currents

Environmental changes in the characteristics listed in table 3-1 can lead to a loss of SAV in areas where it once occurred, although the plants can tolerate some degree of natural variability (for example, seasonality in temperature and light or occasional storms). Moreover, the loss of SAV in itself often leads to habitat changes that can prevent SAV from recolonizing an area. Consequently, **historical occurrence of SAV in a particular area is by itself a poor indicator of a site's suitability for SAV restoration.** That is why it is important to evaluate the physical and geological habitat before undertaking any SAV restoration project. Nevertheless, specific habitat requirements for SAV in the Chesapeake Bay are not yet fully understood, and it is often difficult to pinpoint one or more particular habitat characteristic as *the* factor or factors that limit SAV.

The following sections provide guidelines for measuring the habitat requirements identified in table 3-1 as well as other physical variables that can affect habitat suitability for SAV.

Though physical damage to SAV and its habitat can occur when current and wave intensities increase well beyond the levels needed by plants to facilitate carbon and nutrient uptake from the water column, SAV survival and growth are dependent on moderate currents derived from tidal flows or wave action (Koch 2001). SAV growth may be limited in shallow areas by high wave energy because of the waves' potential to physically damage plants, especially canopy-forming species. Waves may also inhibit SAV colonization by constantly shifting sediments and increasing concentrations of TSS, both of which reduce



light transmission. Furthermore, when wave exposure is high, SAV may be forced to colonize deeper areas where light transmission is greatly diminished, constraining plant vigor and success. Wave exposure is a critical habitat variable when coupled with other habitat variables, such as light penetration; however, specific habitat requirements for maximum wave exposure are still being established for SAV in the Chesapeake Bay. Contact Dr. Evamaria Koch (appendix B) for the most recent information on this topic.

The impacts of current velocity can differ among SAV species and also vary depending upon the developmental stage of a bed. Marine species can typically tolerate current velocities ranging from 5 to 100 cm s⁻¹. Freshwater species are generally less tolerant of strong currents and more tolerant of stagnant water and therefore tend to colonize in areas with velocities between 1 and 50 cm s⁻¹. However, because stagnant or low-flow environments may limit the availability of carbon and nutrient molecules for uptake, intermediate water flow conditions seem optimal for SAV growth. In either environment, established SAV beds with denser biomass and more developed root and **rhizome** systems may be more tolerant of greater currents because of their ability to attenuate the energy more effectively than young or newly established beds.

Expensive current and wave monitoring equipment is not necessary to evaluate site suitability. Koch and Verduin (2001) described simple, inexpensive methods to quantify currents and waves (see Dr. Evamaria Koch, appendix B). Currents and waves should be monitored for at least 2 weeks to account for variation

Water Depth and Tides

in wind patterns. Two approaches can be used to evaluate whether current velocities and wave heights at a potential restoration site are suitable for SAV:

- Measure currents and waves in nearby SAV habitat and compare your results with conditions at the potential restoration site. If currents and waves at the potential restoration site are more than 10% greater than those present at the nearest SAV bed, then the site may not be suitable for SAV restoration. Remember that SAV will attenuate currents and waves, and this should be taken into consideration when comparing sites.
- If there are no SAV beds nearby, compare your data to average conditions in areas colonized by SAV (see, for example, Koch 2002). Wave heights in SAV-colonized areas of the Bay are typically less than 10 centimeters (cm) on a daily basis and approximately 40 cm during wind events. Current velocities are typically 3 to 10 cm s^{-1} . Areas in the Bay with currents stronger than 30 cm s^{-1} are unlikely to support healthy SAV populations.

Because transmitted light is attenuated with increasing water depth, the amount of light available for photosynthesis is reduced as depth increases. Throughout the Chesapeake Bay, SAV typically occurs at depths less than 2 m. The likelihood of restoration success is severely diminished at depths greater than 1.5 m.

In estuarine systems, depth at any site varies with tidal stage. Most SAV species cannot tolerate desiccation, and SAV will probably not survive if a site is so

Sediment Characteristics

shallow that it is exposed during every low tide. This means that in areas with a large tidal range, SAV beds are often restricted to deeper areas relative to the mean tidal level. However, when a large tidal range is coupled with low light penetration, SAV may not survive even in these deeper areas (Koch and Beer 1996). In general, the ideal depth for SAV restoration projects is between the low-tide water level and a depth of 1.5 m.

There is a relatively wide range in sediment grain size measured in SAV beds (table 3–1). Consequently, grain size does not appear to be a major parameter limiting SAV growth. In contrast, the percent of organic matter in the sediment can be a limiting factor. Sediments with more than 5% organic content may limit the growth of high-salinity SAV species, such as *Z. marina*, whereas freshwater species may tolerate up to 16% organic content. Sediment organic content is estimated via combustion (Erftemeijer and Koch 2001).

The degree of sediment compaction may also play a role in SAV colonization. Some Bay sediments are composed of compacted **peat**, particularly in areas adjacent to erosional marshes. These areas are unsuitable for SAV establishment because of the inability of SAV seeds to become recruited into the sediment (Stevenson et al. 2002). Although mature shoots could be planted in these areas, the sites are poor candidates for restoration because of the low likelihood of natural recruitment and population expansion and the possibility for high turbidity levels.

BIOTIC PARAMETERS

Sediment sulfide concentrations can greatly influence the survival and growth of SAV. In general, porewater concentrations of 1 mM and higher are considered toxic to SAV (Koch 2001). Consequently, areas characterized by fine-grain, black mud with a distinctive rotten-egg smell should immediately be ruled out as potential restoration sites.

In addition to the physical, geological, and chemical characteristics associated with a potential SAV restoration site, it is important to assess the potential impacts of a site's biotic parameters. These can include the current SAV community (distribution, biomass, and species composition), the presence of grazers (waterfowl, crabs, fish), the infaunal community (worms), and other animals known to act as bioturbators (rays).

In the case of existing SAV populations, restoration should not be considered at sites where SAV already exists, and it is generally recommended that restoration take place outside an area that could be naturally revegetated (Short et al. 2002). Though it may be tempting to enhance an area of patchy distribution, it is best to not attempt this. These patchy areas can provide ecological functions similar to areas of continuous cover (Thayer et al. 1997). Patchy areas have been shown to act as important habitat for many important species, such as blue crab, black sea bass, Atlantic croaker, and pink shrimp (Noble and Monroe 1991), sometimes in densities nearly equal to those found in continuous beds



(Murphey and Fonseca 1995). Patches are also dynamic and can grow or retreat in different directions within an area in different years.

To ensure that a restoration project does not encroach within the naturally fluctuating area of an existing SAV bed, it is important to understand how the species in the existing bed reproduce. SAV species spread either vegetatively, via root and rhizome extension into nearby areas, or reproductively, through seed production. The seeds of SAV are typically too heavy to travel a long distance by water current alone, but may do so when still attached to floating shoots. In the case of eelgrass, sites within 100 m from a natural bed are considered within the range of natural recruitment because of the influence that tidal currents and wind can have on detached, reproductive shoots (Orth et al. 1994; Harwell and Orth 2002). Conversely, transport of seed-bearing eelgrass fragments that have deteriorated and sunk to the bottom may be arrested by *Diopatra cuprea*, a common tube-building worm that often incorporates these fragments into its tube cap walls (Harwell and Orth 2001). Large-scale dispersal mechanisms have not been documented for other Chesapeake SAV species (table 3–2); thus, separation of restoration sites from existing beds or patchy areas need only be several tens of meters or less in most cases. As mentioned in chapter 2, a survey of SAV species growing under similar habitat conditions near your potential restoration site can be indicative of which species are best suited for use in your project.

Table 3-2. Reproductive strategies of selected SAV species in the Chesapeake Bay

Species	Reproductive Strategy
<i>Ruppia maritima</i>	Vegetative reproduction via creeping rhizome; sexual reproduction in late summer
<i>Vallisneria americana</i>	Vegetative reproduction via rhizomes and tubers; sexual reproduction in late summer; seed dispersal in fall
<i>Potamogeton perfoliatus</i>	Vegetative reproduction via tubers and resting buds; sexual reproduction July–September; seed dispersal in early fall
<i>Potamogeton pectinatus</i>	Vegetative reproduction via rhizomes and tubers at leaf/stem junction, which break off; sexual reproduction in June–July; seed dispersal in late summer and fall
<i>Elodea canadensis</i>	Sexual reproduction in July–September
<i>Zannichellia palustris</i>	Sexual reproduction in March–May

Source: Stephan et al. 2002.

Because the presence of grazers, such as ducks, geese, swans, and various submerged species, is not always immediately apparent, the potential for them to impact a restoration effort can be underestimated or overlooked. The Chesapeake Bay is an important flyway for migratory waterfowl, and SAV is a nutritious and desirable food source for several diving duck species, such as redhead (*Aythya americana*) and canvasback ducks (*Aythya valisneria*). While consumption of SAV by these native species is a part of the Bay's natural



ecology, nonnative species, such as the mute swan (*Cygnus olor*), can add immense feeding pressure from which the grasses often cannot recover. Each adult mute swan can eat up to 8 pounds (lbs) of underwater grasses daily, while aggressively squeezing out native waterfowl. Approximately 20 more lbs per day of SAV may be uprooted during feeding (AFC 2003).

Although federal legislation passed in 2004 removed an ambiguity in the Migratory Bird Treaty Act to allow elimination of the offending mute swans, the Atlantic flyway population is currently estimated at more than 14,000 birds, and this population is growing at an average rate of 6% annually (AFC 2003). Maryland and Virginia (3,624 and more than 560 swans, respectively, in 2002) have the highest population growth rates in the flyway, and the swans have few predators other than humans.

The population at which key natural resources will be adequately protected is not known; however, when Maryland's mute swan population was less than 500 birds, their adverse ecological impacts were negligible (AFC 2003). Until the population of mute swans in the Bay is brought under control, areas known to be frequented by mute swans should be avoided as restoration sites unless adequate protection can be provided through the use of **exclosures**.

The occurrence of seed grazing by crustaceans and fish may be of particular importance to projects relying on seed distribution as a primary means of restoration. Research has shown that consumption by blue crabs and Atlantic

croaker, two common inhabitants of Chesapeake Bay SAV beds, can cause significant eelgrass seed loss in confined areas (Fishman and Orth 1995). Incorporating a combined strategy of exclosures and avoidance of blue crab or croaker “hot spots” for small-scale restorations or test plots may deliver positive results. It may be difficult to screen crabs and fish out of large restoration areas.

Bioturbation, or the constant disruption of soft-sediment bottoms by animal burrowing and feeding, may render sites that have been identified as potential SAV restoration sites unable to support growth (Davis et al. 1998). Bioturbation activities not only mix the sediment layers and cause substantial resuspension of the sediment and its transport by waves and currents, but also alter the processes of nutrient cycling, redistribution of organic material, sediment oxygenation, and organic decomposition. Potential direct impacts on SAV bed health or restoration success include disruption of root-rhizome matrices and decreased seed germination.

The type and magnitude of bioturbation can be difficult to quantify without using underwater video or diver surveys to determine the extent to which bioturbating organisms inhabit a site. Surface fauna can be assessed using simple quadrant sampling, while **infauna** must be sampled using benthic cores. In the Chesapeake Bay, the cownose ray (*Rhinoptera bonasus*) has been documented destroying existing SAV beds (Orth 1975) and transplanted SAV (Fonseca et al. 1994, 1996) in search of food. The nonnative green crab's foraging behavior likewise damages SAV habitat by tearing or cutting grasses

WATER QUALITY PARAMETERS

near their base or dislodging transplanted shoots (Davis et al. 1998). In other regions, destruction of SAV by bioturbation has likewise been documented for horseshoe crabs, burrowing shrimp, lugworms, sand dollars, hermit crabs, and stone crabs.

Because the initial establishment and expansion period is especially important for restoration projects in which SAV is installed at low densities, bioturbators have the potential to significantly decrease restoration success. If benthic surveys reveal significant bioturbation activity at an otherwise ideal restoration site, restoration should be complimented by exclosures or baited traps within caged areas to reduce damage to SAV (Davis et al. 1998).

Water quality is measured and monitored for a multitude of reasons. In the context of this handbook, water quality parameters can be used to select among potential SAV restoration sites or to monitor changes in water quality after a restoration effort.

Creating a sampling design will require making important choices in parameters to measure, monitoring site selection, and sampling frequency and duration. You should strive toward justifying every aspect of your design during the planning stage. Every measurement should be made purposefully, with the knowledge of how the collection and analysis of these data will further your project goals. Following the guidelines set forth in this chapter will help you to

Choosing Parameters to Measure

design a scientifically sound sampling procedure while minimizing wasted time and effort. Finally, regardless of the scope of your sampling effort, your design must include provisions for ensuring data quality and control.

Research has revealed very strong linkages between water quality and the occurrence and health of SAV. Exhibit 3-1 describes some of the important parameters that affect water quality relevant to SAV. Though time and budget may limit the extent to which you are able to incorporate water quality monitoring into your SAV restoration project, it is important to note that some parameters (that is, oils, water color, and suspended solids) can be easily and quickly estimated visually and that none of these tests are particularly difficult to perform. Because often more than one parameter contributes to poor water quality conditions at a potential restoration site, it is helpful to monitor as many parameters as possible given the opportunity and funds.

Light

Beyond the water quality parameters described in exhibit 3-1, the most important factor influencing SAV growth and distribution is the availability of sufficient light at relatively shallow depths (<1.5 m). The amount of light available at a given water depth reflects the cumulative impacts of nutrients, suspended particles (algae, detritus, and sediment), and water color on light transmission. The **percent of light through water** (PLW) is a measure of available light that accounts for the impact of those water quality parameters on light transmission through the water column (figure 3-1). The light available

Exhibit 3–1. Water Quality Parameters Affecting SAV Growth (p.1)

Plankton Chlorophyll-a: Chl-a is a measure of algal biomass and is an indicator of nutrient concentrations in the water column. Consistently high chl-a concentrations ($>15 \mu\text{g L}^{-1}$) limit SAV.

Dissolved Oxygen: Oxygen is a byproduct of photosynthesis and is required by all animals for respiration. Adequate concentrations of dissolved oxygen (DO) are indicative of a healthy aquatic ecosystem. Low DO, particularly during the daytime, can indicate a state of decay from organic overenrichment.

Metals: Metals can be toxic to plants and animals even in very small amounts.

Nutrients: Phosphorus (P) and nitrogen (N) are essential for plant growth. Excess nutrient levels limit SAV by promoting phytoplankton and epiphyte growth, reducing the amount of light available to SAV.

Oils: Oils can coat important organs of *intertidal* plants and animals, inhibiting photosynthesis, respiration, and reproduction.

Pesticides/Herbicides: Pesticides and herbicides may be dissolved in water or attached to particles washed downstream. Some of the chemicals used to control terrestrial pests are also toxic to aquatic plants and animals.

Salinity: Salinity is another water characteristic that affects the regime of SAV species that can survive at a specific site. Table 1–1 and figure 4–1 contain additional information.

Suspended Solids: Total suspended solids (TSS) include algae, detritus, and inorganic matter, including sediment. High concentrations of TSS ($>15 \text{mg L}^{-1}$) limit SAV by decreasing the amount of light available for photosynthesis.

(exhibit continues on next page)

Exhibit 3-1. Water Quality Parameters Affecting SAV Growth (p.2)

Temperature: Plants and animals have optimal temperature ranges for growth, survival, and reproduction. Elevated temperatures can indicate that critical shade elements (that is, shoreline tree canopy) were lost or that emergent structures (that is, offshore breakwater) are restricting water circulation. Global warming may also affect local water temperatures over decadal time scales.

Water Color: Color is an indicator of the chemical and biological composition of water. Green indicates an abundance of algae or phytoplankton. Brown indicates high amounts of sediment. Brown-black indicate the presence of tannins and other leachates from organic substrates like peat. Orange indicates iron hydroxides resulting from acid mine drainage. Gray can indicate the presence of raw sewage or aluminum.

to SAV is further reduced by the amount of **periphyton** growing on the SAV leaf surfaces. The percent of light at the leaf (PLL) accounts for the effects of periphyton in addition to nutrients, particles, and water color (figure 3-1). These complex relationships are explained fully in Batiuk et al. (2000).

Your project goals and objectives, your knowledge of the sites, and your available resources will govern which light parameter to measure. Calculating PLW requires an estimate of the light attenuation coefficient (K_d), which can be measured directly with a light sensor or estimated from Secchi depth. When an estimate of the light attenuation coefficient is the only measurement available, PLW is an acceptable, though not completely accurate, estimate of light reaching the plant. In contrast, calculating PLL requires an estimate of K_d plus

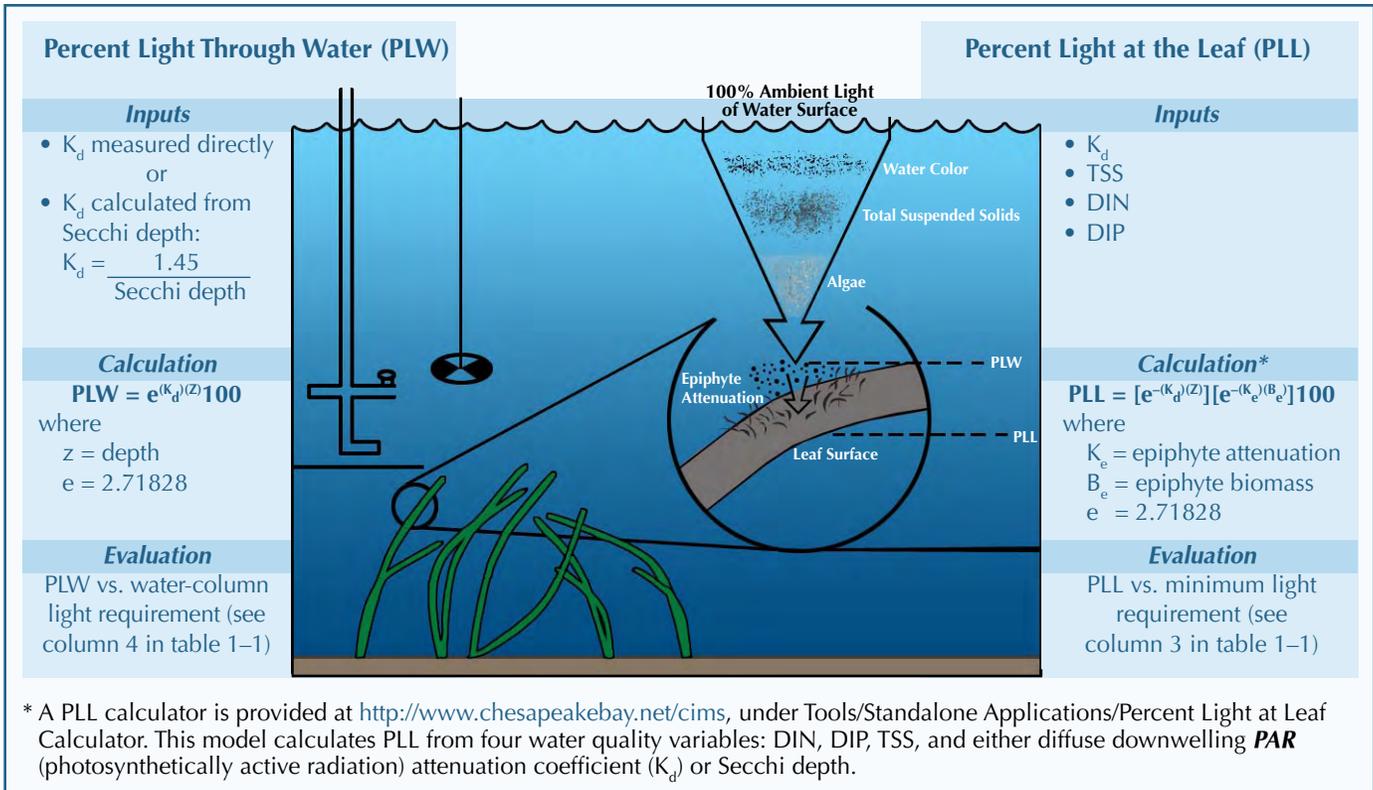


Figure 3-1. Calculation of PLW and PLL and comparisons with their respective light requirements. SOURCE: BATIUK ET AL. 2000

Other Water Quality Parameters

analysis of water samples for concentrations of TSS, DIN, and DIP parameters for which recommended habitat requirements are given in table 1-1. PLL is a more robust and comprehensive measure of the amount of light reaching SAV because it accounts for light reduction by periphyton as well as water column effects. Consequently, it is the recommended approach for best determination of the amount of light reaching SAV.

While costs are always a concern, you may elect to have your water samples analyzed for other water quality parameters in addition to DIN, DIP, and TSS. For example, it may be useful for you to distinguish between organic (that is, algae) and inorganic (that is, sediments) constituents of TSS. By including plankton chl-*a* in your analysis, you may gain insights into the root cause of poor water quality at your sampling sites or more regionally throughout the watershed.

The CBP has adopted minimum SAV habitat requirements for light, chl-*a*, TSS, DIN, and DIP under different salinity regimes (table 1-1). Depending upon your project goals, these requirements should be used to evaluate and interpret your water quality results. The CBP Chesapeake Information Management System (<http://www.chesapeakebay.net/cims/index.htm>) has several spreadsheet tools in addition to the PLL Calculator that will help you evaluate your results.

SELECTING MONITORING SITES

The particular goals of your restoration project will generally dictate where to evaluate water quality. Nevertheless, some situations will require making choices about where to sample, particularly if you are trying to evaluate habitat over a large area, extrapolate your results to unmonitored areas, or compare your results with those from existing monitoring sites. Exhibit 3–2 contains some basic guidelines for the appropriate number and proximity of monitoring sites derived from research, experience, and expert opinion.

SAMPLING FREQUENCY AND DURATION

Monitoring can be conducted year-round or seasonally during the SAV growing season (March through November for meso- and polyhaline species or April through October for tidal fresh and oligohaline species). The longer a site is monitored, the more accurate the water quality evaluation at that location will be across different tidal cycles and under various climatic conditions (for example, summer vs. winter or dry vs. wet years). Monitoring only during the height of the growing season (July and August) will not reveal water quality conditions during particularly important periods, such as in the spring when growth begins, nor will it reveal the range of conditions experienced by SAV throughout the growing season. Most water quality sampling efforts throughout the Chesapeake Bay are conducted at a frequency of monthly, biweekly, weekly, or continuously.

Monthly Sampling

Most tidal water quality sampling in the Chesapeake Bay is conducted at least once per month. The MD-DNR conducts monthly sampling at mainstem Bay

Exhibit 3-2. Selecting Monitoring Sites

- ❑ Plan for fewer monitoring sites along shorelines that are relatively straight and pristine (little or no development), contain few creeks and outfalls, exhibit good tidal flushing, and are sheltered from waves. In these admittedly rare situations, inter-site distances of 5 to 6 kilometers would yield representative data. Sites can be conveniently located at the end of piers or in areas readily accessible by boat; however, note that sampling should be avoided in areas recently disturbed by boat traffic.
- ❑ Plan for more sites along heterogeneous, less pristine shorelines. However, try to establish at least one monitoring station along a more natural, less-developed shoreline relative to your other sites to serve as a control.
- ❑ Sample all sites on the same date to minimize weather-related variability. Note weather conditions on the sampling dates as well as during several days prior to sampling.
- ❑ Midchannel areas might be more convenient to reach by boat, but try to restrict sites to near-shore, shallow (mean depth ≤ 1.5 m) areas.
- ❑ You may be able to add one or more sites to your effort by utilizing data from established sampling stations already being monitored by another agency. If so, coordinate your monitoring schedule with that agency so samples are collected on the same dates. It would also be wise to have all water samples analyzed by the same laboratory.

Biweekly and Weekly Sampling

sites in support of CBP goals to evaluate long-term trends in water quality. Because of the limitations of predicting water quality conditions using data from infrequent sampling (often conducted during good weather conditions), sampling at a monthly or lower frequency is recommended only under some or all of the following conditions:

- The monitoring effort faces severe budgetary constraints
- The area to be monitored is large, and frequent sampling is logistically not feasible
- Water quality variability is small at the monitored sites and frequent samples are not needed to measure variability over time.

Water quality is more commonly evaluated on a biweekly basis at potential SAV restoration sites or at sites specifically selected for long-term monitoring based on the presence or absence of SAV. Organizations interested in identifying potential SAV restoration sites, such as the Alliance for the Chesapeake Bay (ACB), sample biweekly throughout the SAV growing season. A biweekly or weekly sampling frequency is recommended under the following conditions:

- The area of interest is relatively small
- Financial resources permit weekly or biweekly sampling during parts of the year but are not sufficient to monitor throughout the year

Continuous Sampling

- Sites are typically shallow-water areas that support SAV or algae, or exhibit physical conditions that increase temporal variability
- Sites have been identified as potential SAV restoration or monitoring locales.

Recent efforts to monitor water quality in shallow-water sites sometimes utilize automated devices that continuously record in-situ water quality parameters such as turbidity, DO, salinity, **conductivity**, temperature, and **pH**. Continuous sampling is often done in conjunction with weekly, biweekly, or monthly sampling for TSS, chl-*a*, and other parameters. Continuous sampling provides excellent insight into water quality conditions at one site under various tidal cycles and climatic conditions. However, continuous sampling is very expensive and time consuming. Consider using continuous sampling under the following conditions:

- The site is spatially homogeneous and can be well characterized by one monitoring site
- The site is either a restoration or reference site that is being evaluated for other parameters, such as plant growth and survival, that are monitored at a lower frequency (such as biweekly during the growing season)
- Resources such as time and funds are plentiful.

Post-Restoration Sampling

Sampling after the completion of a restoration project is best done by comparing post-restoration measurements to the following:

- 
- Historical benchmarks of water quality before impairment, as determined by long-term data sets
 - Water quality of unimpaired reference sites that are similar in depth, wave exposure, currents, sediment type, and so forth, to the restored site
 - Habitat criteria established for the specific location
 - Expert opinion, when data are not available.

An alternative, or complementary, method of evaluating a restoration effort is to compare water quality post-restoration with water quality measurements pre-restoration. This method can determine whether a restoration effort has enhanced water quality at a site; however, by itself, this method is not sufficient to evaluate whether a restoration project has succeeded in restoring water quality at a site to pre-impairment levels. Regardless of your approach, it is vital to tailor your sampling objectives and design to support your particular SAV project goal or goals.

Selecting an appropriate sampling frequency and duration depends upon your specific project goals and the water quality parameters you have chosen to evaluate. Your efforts will also be constrained by the total number of monitoring sites and available time, personnel, and funding. Table 3–3 contains general guidelines for selecting an appropriate sampling design in terms of frequency, duration, and water quality parameters based on the particular goal of your monitoring project.

Table 3-3. Suggested sampling designs for different monitoring goals

Monitoring Goal	Frequency	Duration	Parameters
To identify potential SAV restoration sites	At least twice monthly	Tidal fresh/oligohaline: April 1–October 31 Mesohaline and polyhaline: March 1–November 15	TSS, chl- <i>a</i> , DIN, DIP, K _d
To establish a long-term (>3 – 5 yrs) database or identify trends over time	At least once monthly	Continuously, throughout the year	TSS, chl- <i>a</i> , total volatile solids (TVS), total N (TN), total P (TP), K _d
To perform a short-term study or directed effort	Biweekly, weekly, or continuously	Minimum 3–6 months, depending on purpose (for example, determining seasonal or diel variability or spatial variability in small area)	As many as resources and time permit

EQUIPMENT AND LABORATORY REQUIREMENTS

Once you've designed your water quality sampling effort, you'll need to obtain the appropriate sampling equipment and set up a contract with a laboratory to analyze your samples. These planning aspects can take considerable time up front; however, if implemented properly, they require little time and effort in subsequent years.

It may be possible to borrow rather than purchase large equipment such as a boat, motor, trailer, and towing truck. Smaller items that may need to be purchased for routine sampling, along with some retail sources, are listed in appendix C. Sampling equipment should be standardized to allow for data comparison and transferability to other users.

Choose a reputable analytical laboratory to handle your samples. Two laboratories are recommended for the analysis of water samples in the Chesapeake Bay region (exhibit 3–3). Analytical laboratories require a contract or binding agreement in the form of a purchase order (PO) or other service arrangement (see appendix F for a sample PO). Work with your purchasing department and the point of contact for the laboratory to create an acceptable

Exhibit 3–3. Recommended Analytical Laboratories in Chesapeake Bay Region

Chesapeake Biological Laboratory

P.O. Box 38
1 Williams St.
Solomons, MD 20688
Point of Contact: Carl Zimmerman
Phone: 410-326-7252
Fax: 410-326-7209
Email: carlz@cbl.umces.edu

Virginia Institute of Marine Science

P.O. Box 1346
Rt. 1208, Greate Road
Gloucester Point, VA 23062-1346
Point of Contact: Carol Pollard
Phone: 804-684-7213
Fax: 804-684-7097
Email: pollard@vims.edu

SAMPLING PROTOCOL

PO or contract agreement. The contract or PO should be established on an annual basis and signed by the appropriate signatory officials several months before sampling begins. Allow a minimum of 3 months in the period of performance for the laboratory to complete its sample analyses and billing.

Depending on the practices of your installation's purchasing department and the source of project funding, unspent money remaining at the end of the year may or may not carry over to the following year. Typically, unspent funds cannot be rolled over, although you can sometimes extend the period of performance to allow full expenditure of the funding. Either way, investigate these details before work begins and define the terms of the contract to ensure efficient use of resources.

After deciding where, when, and what to monitor, you must establish a standard protocol for measuring water quality in the field. The protocol should include procedures for taking field measurements and preparing, storing, and delivering water samples to an analytical laboratory. You should also incorporate any site-specific procedures or requirements related to safety, communications, access, and security clearance into the field protocols. Appendix G contains a suggested protocol for measuring selected parameters, such as water depth and light attenuation, in addition to collecting water samples. Appendix H contains a sample field data form. Data forms should be designed to provide sufficient space to record each variable, along with a comment field to record



observations related to weather, boat traffic, presence of grazers, and any other relevant environmental conditions. These comments often become important when analyzing and interpreting data. Ideally, you should print your field data sheets on waterproof paper (see appendix C) and record all data in pencil (2.5 or harder) in case they are inadvertently exposed to water. Rigorously following your chosen protocol during every sampling trip will minimize measurement error and discrepancies between sampling results.

You will also need a protocol detailing how the water samples will be processed once they are collected. This protocol should include instructions for handling, filtering, labeling, and storing samples prior to laboratory analysis (see appendix I). Water samples must be either filtered on-site with a handheld pump immediately after they have been collected or filtered in a laboratory within 6 hours of collection. If you are holding samples for laboratory filtration, the samples must be kept chilled on ice in a cooler to minimize further conversion of nutrients and to slow down photosynthetic activity or metabolism. For consistency and quality assurance and control (QA/QC) purposes, the same filtering protocol should be followed throughout the sampling season.

Total holding time refers to the time between sample collection and ultimate processing and may differ between analytical laboratories. Typically, once samples have been filtered and frozen or refrigerated as needed, a 28-day

QA/QC

holding time is permitted within EPA guidelines. Prior to beginning any fieldwork, you should contact the laboratory to determine the appropriate holding time, develop a schedule for delivering samples, and review your protocols for sample handling and preparation.

QA/QC at SAV sites prior to, during, and after restoration should follow standard EPA methods (<http://www.epa.gov/OWOW/monitoring/>) or alternatively defined reference methods with known **detection limits**. Most of the protocols outlined on the EPA Web site provide recommendations on QA/QC procedures that should be followed and documented to ensure quality of the samples and data. Analytical laboratories will have their own QA/QC procedures and requirements to ensure the accuracy and precision of reported results. Here are some additional QA/QC measures to implement as part of your protocol:

- **Field duplicates:** A field duplicate consists of one additional sample taken at the same time at a given site. At least one of these should be taken during each sampling trip or each day of a multiday sampling trip. Field duplicates should yield nearly identical water quality measurements. *Note:* It is important that both sampling devices are submerged at the same time and at the same water depth to be considered true field duplicates.
- **Laboratory duplicates:** An analytical laboratory uses duplicates to ensure proper operation of its analytical equipment and to evaluate the consistency of your sample preparation and filtering procedures. For the latter, conduct

DATA MANAGEMENT PROTOCOLS AND DATA-SHARING PROVISIONS

the same sample preparation procedures *twice on the same sample*, so that two sets of samples are sent in for the same site. You may need to take a larger-than-normal sample to ensure that enough water is collected to process the two samples. As a general guideline, 10% of the samples sent to the analytical laboratory should be laboratory duplicates.

- **Blanks:** Analytical laboratories also run blanks to test the accuracy of their analytical equipment. A blank consists of a sample of deionized or distilled water and should always return a value of “0” for the tested parameters. The collecting agency should submit blanks to the laboratory for analysis as well. These blanks will act as redundant checks of instrument accuracy and will identify contaminants in the distilled water that may be attributable to inadequately washed sample containers. Once again, 10% of the samples sent to the laboratory should be blanks.

Data management protocols are procedures to check the accuracy and completeness of field data forms and electronic data entry. Data sheets should be scrutinized as soon as possible to ensure that all data fields have been accurately completed. Data entry protocols should include procedures such as post-entry data checks by non-entry staff, encoding minimum and maximum values for parameters, and running programs to identify missing or illogical data entries.

Despite the widespread and seemingly comprehensive water monitoring efforts taking place throughout the Bay, there is a real need for water quality data from inshore areas, particularly at potential or restored SAV habitats. You are encouraged to share your data with the CBP SAV Task Group (see Mike Naylor, appendix B) for incorporation into the regional database. Electronic data may be transferred either directly or through one of several general oversight organizations, such as the Freshwater SAV Partnership housed at the Chesapeake Research Consortium (see appendix J for a list of oversight organizations). To facilitate regional data-sharing, you should include the following provisions and information to help ensure that your water quality data are compatible with regional electronic data sets:

- Associated ***metadata***
- Units of measure
- Methods and protocols
- Detection limits
- QA/QC procedures
- Sampling locations (GPS coordinates)
- Sample depths
- Sample dates.

CHAPTER FOUR Restoration

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

—Society for Ecological Restoration International Science & Policy Working Group, 2004

BENEFITS OF RESTORATION

The restoration component of an SAV program includes planting one or more SAV species in an area where SAV habitat requirements are met. However, restoration need not be restricted to planting SAV. Restoration activities can include efforts to improve water quality or habitat, such as shoreline stabilization or stormwater retrofits. Activities that improve water quality and habitat either on-site or upstream in the watershed can promote natural recruitment by SAV. In other words, “Clean the water and the SAV will come!”

Planting SAV typically involves a long-term commitment of resources to a specific site, and the decision to restore a degraded area should not be taken lightly. However, the benefits of undertaking SAV restoration at a DOD installation can extend far beyond the confines of a particular site. For instance, restoration promotes and demonstrates environmental stewardship by improving water quality and aquatic habitat. Improved water and habitat

PLANNING THE RESTORATION PROJECT

quality can increase opportunities for recreation, promoting staff morale and productivity. Finally, restoration often leads to public recognition and a greater appreciation for the installation by the surrounding community.

An ill-planned restoration can be more detrimental to a degraded system than no action at all. Consequently, considerable thought should go into the planning and design of a restoration effort once funds are secured and all stakeholders are committed to the restoration. This chapter discusses each of the required elements of a successful restoration plan, as outlined in exhibit 4-1.

Exhibit 4-1. Required Elements of an SAV Restoration Plan

- ❑ Clearly stating restoration goals and objectives
- ❑ Identifying potential sites based on surveys and habitat assessments
- ❑ Identifying one or more suitable SAV species
- ❑ Conducting preliminary trials involving test plots and/or SAV floats
- ❑ Developing a budget-conscious, comprehensive restoration design
- ❑ Identifying health and safety considerations
- ❑ Conducting post-restoration monitoring
- ❑ Developing procedures for data management and QA/QC.

Clearly Stating Goals and Objectives

No restoration effort should commence until all parties involved in the restoration agree on the goals and specific objectives of the project. Goals of an SAV restoration could include one or more of the following:

- Establishing SAV in an area with acceptable water quality and habitat characteristics
- Controlling undesirable or invasive species and promoting native SAV species
- Improving water quality
- Stabilizing sediments
- Enhancing wildlife or fisheries habitat
- Contributing to Baywide SAV restoration goals
- Increasing the aesthetics of the installation's natural environment
- Improving recreational opportunities for installation staff
- Increasing public awareness of the importance of SAV beds, improving water quality, and improving habitat through education and outreach.

Once goals are set, establish specific measurable targets and a concrete time frame for meeting the targets. Examples of measurable targets or goals include restoring 10 acres of SAV by 2010, improving water quality to levels consistently higher than current levels within 5 years, or reaching out to 100 schoolchildren per year. Ask independent experts (see appendix B) to review the project goals and objectives to ensure that they are appropriate and

Identifying Potential Restoration Sites

feasible. Continuously revisit the objectives during the design phase to ensure that the objectives, design, and budget remain on track, and revise if necessary.

A good restoration plan should explicitly describe how information from SAV surveys (chapter 2) and habitat evaluations (chapter 3) will be gathered and analyzed to identify and select among potential restoration sites. The plan should incorporate the following key points from chapters 2 and 3:

- A thorough survey of the historic and current SAV distribution should precede and guide efforts to evaluate habitat suitability for SAV.
- Habitat surveys should first encompass an evaluation of physical habitat characteristics, the results of which should direct your efforts toward monitoring water quality.
- Specific habitat requirements have been developed for SAV throughout the Chesapeake Bay (see table 1-1 and Batiuk et al. 2000). Evaluate the results of your habitat surveys and water quality monitoring against those benchmarks to select restoration sites.
- Although nutrient enrichment is one of the main negative impacts humans exert on SAV, other more localized disturbances should also be considered and avoided when choosing a restoration site. These disturbances include foot or boat traffic and the presence of docks or piers.
- Site accessibility, either for monitoring purposes or to facilitate the use of volunteers, can figure into your site selection, but should never be more important than habitat suitability.

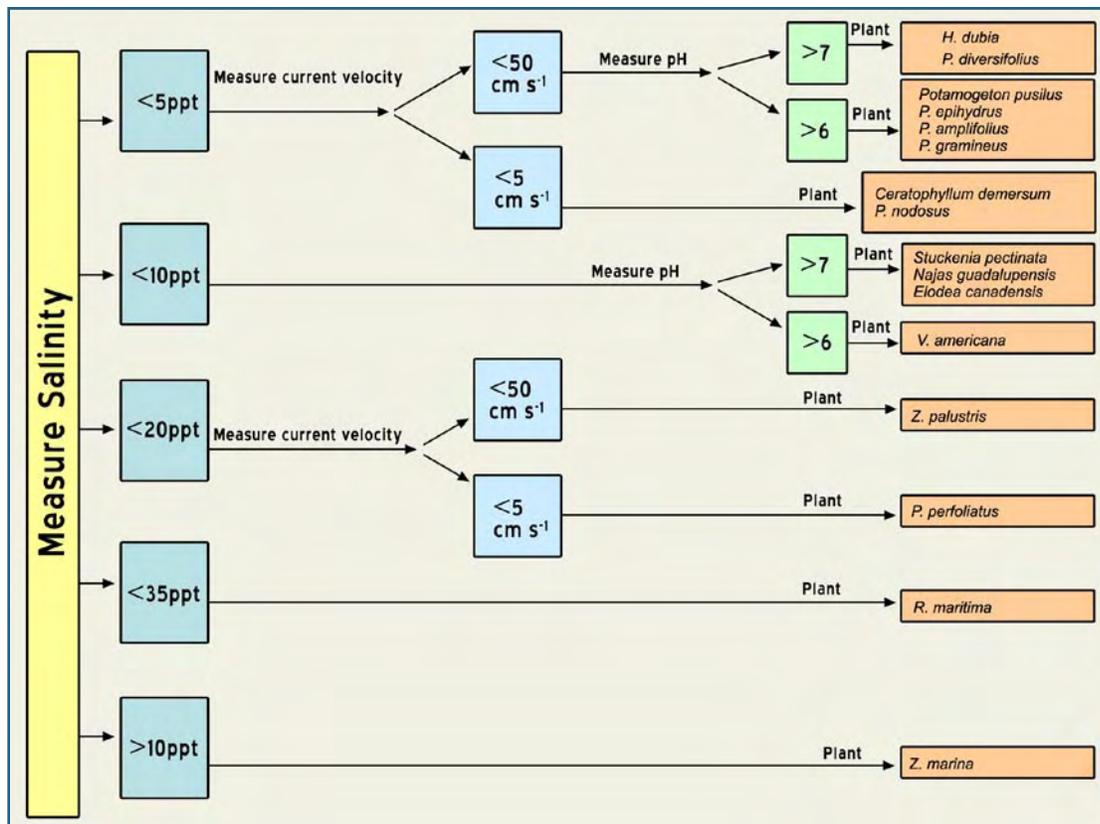
Identifying Suitable SAV Species

The appropriate SAV species for a given site depends on the environmental conditions at that site. Your choice of species is far more limited if the salinity regime of your installation waters is polyhaline (>18 ppt) versus tidal fresh to oligohaline (0 to 5 ppt) because fewer SAV species are adapted to high salinity than to freshwater. Make sure that your assessment of salinity is based on long-term average conditions rather than during unusually wet or dry seasons or following extreme weather events.

Your choice of suitable species will also be constrained by different species' adaptations for particular habitat conditions (see figure 4–1). For example, species with floating leaves are generally characteristic of habitats with low current velocities (<5 cm s⁻¹), whereas species with strap-like, submerged leaves will tolerate greater (<50 cm s⁻¹) current velocities. For a review of the salinity tolerances and basic morphology of common Chesapeake Bay SAV species, consult the *Chesapeake Bay Foundation Guide to Underwater Grasses* (http://www.cbf.org/site/PageServer?pagename=resources_pubs_index), the *Field Guide to the Submerged Aquatic Vegetation of Chesapeake Bay* (Hurley 1992), or *Underwater Grasses in Chesapeake Bay & Mid-Atlantic Coastal Waters: Guide to Identifying Submerged Aquatic Vegetation* (Bergstrom et al. 2005).

In many cases, you may maximize the odds of successful restoration by incorporating one or more levels of diversity in your planting design, including genetic, species, functional, and **trophic level** diversity.

Figure 4-1. Flow chart for SAV species selection based on environmental conditions. Note: This information is based on the opinions of experts consulted in preparing this handbook; however, information on these characteristics is limited for many SAV species.





Genetic Diversity: SAV species reproduce sexually, but most species also produce shoots that originate from a common rhizome or root system, or even from stem fragments. Asexual reproduction allows plants to expand quickly and colonize new areas, and individual plants are often genetically identical (**clones**) in areas dominated by a single species. You can increase the genetic diversity at your site by transplanting individuals from different populations or locations. Although potentially more expensive, it will increase the likelihood that your transplanted population can adapt to environmental variability and persist over time. However, never use transplants from populations outside the Chesapeake Bay watershed, and always screen your plant material for **propagules** of potentially invasive species.

Species Diversity: Naturally occurring beds of SAV are often composed of multiple species, particularly in less-saline regions of the Bay. Planting a variety of native species can greatly increase the chances of restoration success, particularly in areas where environmental conditions fluctuate widely seasonally or interannually. Keep in mind that it could take longer to obtain the amount of native plant material necessary for a multispecies restoration project. Multispecies test plantings should be conducted as early as possible in your restoration. An example of a multispecies restoration is located at the Chesapeake Bay National Estuarine Research Reserve (CB-NERR) site at Otter Point Creek, in Maryland (see Julie Bortz, appendix B).

Functional Diversity: SAV species can be grouped into functional types because they fill similar roles within and have similar adaptations to their environments (see exhibit 4-2). By including plants from more than one functional group in your restoration plan, you can establish a community with greater potential to adapt and respond to environmental fluctuations.

Trophic-level Diversity: A very recent development in the field of SAV restoration involves incorporating aquatic organisms from other trophic levels into SAV restoration designs. Dr. Roger Newell (see appendix B) has developed a model that supports further investigation of the potential benefits of oysters to

Exhibit 4-2. Functional Groups of SAV and Their Representative Species

- ❑ **Completely submerged, meadow-forming species with basal leaves:** examples include wild celery (*Vallisneria americana*) and eelgrass (*Zostera marina*)
- ❑ **Species with floating leaves:** examples include water lilies (*Nymphaea spp.*) and water starwort (*Callitriche spp.*)
- ❑ **Species with completely submerged leaves that form leaf canopies at the water's surface:** an example is redhead grass (*Potamogeton perfoliatus*)
- ❑ **Emergent species with upper stems and leaves that protrude up and out of the water:** examples include various SAV species in flowering stages (*Potamogeton perfoliatus*, reproductive; *Heteranthera dubia*, reproductive)

Conducting Preliminary Trials

adjacent SAV beds. Filter-feeders, such as oysters, have a tremendous capacity to improve water quality through their filtration of suspended particles. Projects involving the creation of oyster reefs adjacent to SAV restoration areas are planned or already under way at the U.S. Navy Western Field Annex on the St. Mary's River, Maryland.

Several pre-restoration planning tools have been developed to help you select appropriate species while also confirming the appropriateness of overall site selection. Relatively short-term preliminary trials or pilot studies are often used to evaluate site suitability or assist with selecting appropriate species, densities, planting depth, or other aspects of the design plan. These pre-restoration trials most commonly involve the use of either test plots or SAV floats.

Test Plots: Test plots typically consist of 0.5, 1, 2, or 4 square-meter (m²) plots planted at various densities and depths. The relative success of the plantings will help you test site suitability or other aspects of your design plan. Most agencies and groups conducting SAV restoration throughout the Chesapeake Bay support the use of test plots.

Because little is known about the appropriate size and density for successful plantings, conducting several small-scale experiments may be necessary to determine the best combination of variables. Recommended densities are 10, 50, 100, and 200 plants per square meter. Multiple-species plantings can increase the success of a restoration effort by increasing the probability that

at least one species will succeed (see the section on species diversity above). However, if time and resources are limited, experts recommend that you construct several test plots of a single species, measuring 1 to 2 m², with a minimum density of 100 plants per square meter. Whenever possible, test plots should be enclosed with fencing that sits well above the high tide mark to limit herbivory.

SAV Floats: SAV floats are trays planted with SAV and suspended by a rectangular floating rack constructed of PVC (figure 4-2; see appendix K for construction procedures). The concept of using floats for SAV is based on the Taylor floats used to cultivate oysters in the Chesapeake Bay. Floats allow you to evaluate plant growth at a particular



Figure 4-2. Researchers installing SAV floats.
PHOTOS: J. BORTZ, CB-NERR

Developing a Restoration Design

site without actually planting the SAV in the sediment. SAV floats have been used to select appropriate species, planting times, and planting depths for future restoration (see Julie Bortz, appendix B). SAV floats can also be used to grow plants in light-limited environments because the trays can be preplanted and suspended at various depths.

Restoration projects should incorporate design elements that maximize the likelihood of long-term survival and persistence of the restored SAV community. Some of these design elements or options involve planting SAV at multiple sites, depths, and densities. Other design options include planting in multiple years or at different times of the year, planting different types of stock (that is, whole plants, tubers, bare roots, or seeds), and using fences or exclosures to limit herbivory. Of course, not all design options are appropriate or feasible in all circumstances. Each design option or strategy must be considered in the context of how much plant material, human resources, equipment, and funding are available to properly plan and implement the restoration project.

Plot Size (Restoration Area): The extent of the area to be restored will often dictate the most appropriate planting method (figure 4–3), and constrain the appropriate stock types and species availability for planting (figure 4–4). A single person can manually plant an area 1 by 1 m (0.001 hectare) in size, whereas areas ranging between 50 to 100 hectares are best planted by mechanically broadcasting seeds (figure 4–5). However, the relative success

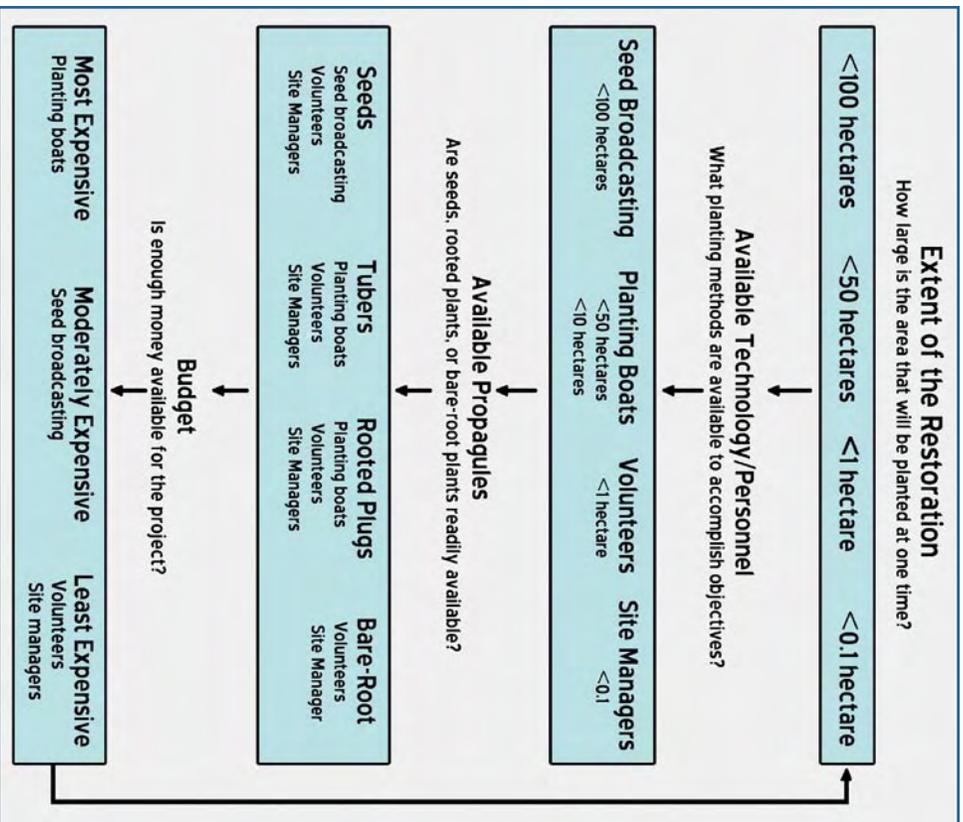


Figure 4-3. Planning the restoration effort based on planting area, methods, propagules, and budgetary constraints.

Figure 4-4. Types of propagules available for restoration efforts: (a) tubers; and (b) bare-root. PHOTOS: J. BORTZ, CB-NERR



of restoration projects using planting machines has been mixed, and stock availability often becomes limiting with increasing plot size.

Planting at Multiple Sites: Planting at multiple sites increases the likelihood that at least some of the restoration sites will experience appropriate conditions for plant survival. Site selection should be guided by water quality monitoring data and habitat evaluations.

Planting at Multiple Water Depths: The chances of restoration success can also be enhanced by planting at multiple water depths, so long as light conditions, wave action, and tidal range are within acceptable ranges. A healthy SAV bed will typically spread on its own into shallower and deeper areas, and planting at different depths can accelerate this process. The availability of sufficient plant material may limit the use of this design strategy.



Figure 4-5. Various SAV restoration efforts around the Chesapeake Bay. PHOTOS: (A) P. KERR, LANGLEY AIR FORCE BASE; (B) CHESAPEAKE BAY FOUNDATION; AND (C) J. BORTZ, CB-NERR

Planting at Varying Densities: The effects of plant density on restoration success are poorly understood. One suggested approach is to plant a larger area less densely, whereas another suggests planting more densely but less broadly. One possible reconciliation of the two approaches is to plant small, dense clumps over larger areas. The optimum density for restoration depends partly on environmental conditions at the site. In general, more adverse conditions (for example, high sedimentation rates, current velocities, and wave energy) may require greater densities of plants. However, until more definitive guidelines are developed, restoration efforts should concentrate on selecting habitat conditions and species that optimize the chances of long-term plant survival, which should encourage beds to attain high densities naturally over time. Where environmental conditions are optimal, lower-density plantings potentially allow a larger area to be restored because of the propensity of healthy plants to fill in gaps.



Planting in Multiple Years: Environmental conditions change from year to year, and an unsuccessful effort in one year does not necessarily preclude success in subsequent years. Planting in subsequent years at or near a previously restored site can augment existing populations or give a relatively unsuccessful site a second chance to become established. Multiyear plantings also allow you to learn from previous experience and adapt and improve your restoration plan; however, more than three attempts at the same site is probably unwarranted.

Planting at Different Times During a Season: Different species have different life cycles that are optimized for the environmental conditions they experience across their habitat ranges. Some species grow and reproduce early in the summer, and others reach their highest biomass later in the season. The optimal planting time for a given species can vary slightly year to year based on changing environmental conditions. If stock material, funding, or equipment use is limited, planting is best in the spring when using vegetative material. Seed casting should occur just prior to germination, which varies by species.

Plant and Seed Sources: SAV can be restored using seeds, vegetative material, or both. Seeds are commonly used if they are readily available and easy to collect, process, and release, as is usually the case for *Z. marina* (see Dr. Robert Orth, appendix B) and *R. maritima*. Broadcasting seeds has proven successful, particularly for higher-salinity species. One option for obtaining seeds is to collect reproductive shoots of desirable species in the field. The shoots can be kept in holding tanks (appendix K) or anchored by buoys in suspended bags

(Pickerell and Schott 2003) until the seeds mature and are released from the pods. Seeds will settle onto the bottom of holding tanks where they can be easily retrieved. If suspended bags are anchored directly over the restoration site, seeds will naturally fall through the net onto the sediment where they will germinate. The buoy-deployed seeding method eliminates the need for seed storage, processing, and growing out intermediate stages in tanks, yet still gives volunteers an opportunity to participate.

Freshwater plants or propagules of *E. canadensis* and *V. americana* are usually available from commercial aquatic plant nurseries (appendix C). Commercial dealers should be able to ensure that the material originated from the Chesapeake Bay and contains no invasive or nonnative species. They should also address your concerns regarding genetic diversity. Other sources of freshwater and oligohaline species include the **micropropagation**/tissue culture labs at Anne Arundel Community College (see Dr. Stephen Ailstock, appendix B) and the University of Maryland Center for Environmental Science (see Dr. Evamaria Koch, appendix B). Marine SAV species are not yet available from these facilities. A few grow-out facilities, such as Piney Point Laboratory (appendix C), propagate native field-harvested *Z. marina*. All lab facilities require 6 to 12 months to gear up their production. Finally, some species can also be harvested in the field and grown out to increase yield. Harvesting wild SAV plants requires a permit and should only be pursued as a last resort because of the potential risk of damaging the donor site.

Coordinating Staff and Volunteers

Exclosures: Exclosures or fences are sometimes used to protect newly planted SAV from herbivory, invasive species, and boaters. Exclosures also make your restoration site easier to find for monitoring. Drawbacks include the cost of materials and difficulties associated with *fouling* or installing them in some areas. To avoid damage from ice, the fencing should be removed during winter and replaced prior to the next growing season, if necessary. The appropriate design (rectangular, shoreline, or cylindrical) and anchoring mechanism depends upon the site. In areas with soft substrates and gentle currents, fencing can be anchored using PVC (polyvinyl chloride) poles (1-inch (in) diameter) no greater than 2 m apart. Fencing should extend at least 0.25 m above the high tide mark and at least 0.25 m into the substrate to ensure protection both above and below the water. Fencing material should either be plastic-coated aluminum or a similar lightweight material with 2- to 4-in openings. Areas with harder substrates and stronger currents require an alternate design (see Smart and Dick 1999).

Coordinating volunteers and supervising personnel during a restoration effort requires planning, organization, and good communication prior to, during, and after the project. A good way to prepare for an activity where many people are involved is to focus on the 5 Ws:

- **Who** will be helping? Volunteers come with varying amounts of experience and it's usually best to mix skill levels within various working groups. If

Health and Safety Considerations

possible, determine each person's level of experience prior to the event, and assign a staff member to oversee each group.

- **What** are the specific tasks that you want to accomplish (for example, plant 10 test plots with 100 plants each)? Think in detail about what needs to get accomplished so that you can tell people what to expect. Will they need to bring a lunch? Should they come prepared to get wet? The more information you can provide ahead of time, the better prepared folks will be on the day of the event.
- **When** should people arrive and when can they expect to finish?
- **Where** should people meet and where will they be working?
- **Why** are you doing this project? You can motivate people by giving them an understanding of the project and telling them how their efforts are making a difference. Prepare and distribute a short written account of the project ahead of time. You can also give an introductory talk describing why you're restoring this site and why you've chosen to plant a particular species. Remember that volunteers should feel appreciated for giving their time. Show your gratitude by providing snacks, drinks, and tokens of appreciation such as hats or T-shirts.

Any SAV restoration project must include safeguards to protect all personnel from work-related hazards. Appropriate safeguards can include requiring daily safety briefings, wearing particular safety apparel (for example, booties,



sunglasses, sunscreen), and incorporating safety-related considerations (for example, equipment checklists and inspections) in all written protocols. Planning and implementing adequate health and safety protocols requires careful consideration of the unique risk factors associated with each phase of the project. Some of the risk factors you should review and address during the planning stages of your project include the following:

- Weather-related hazards
- Stress caused by heat or cold
- Work along shorelines
- Work in shallow and open water
- Scuba diving safety
- Watercraft safety
- Proper use of portable hand and power tools
- Noise
- Underground and overhead utilities
- Wildlife, such as mosquitoes, ticks, venomous snakes, and spiders.

Consult the following internet resources for additional health and safety-related information:

- National Institute for Occupational Safety and Health: <http://www.cdc.gov/niosh/homepage.html>

Conducting Post-Restoration Monitoring

- Occupational Safety and Health Administration: <http://www.osha.gov>
- United States Army Corps of Engineers: <http://www.usace.army.mil/inet/usace-docs/eng-regs/ceso.html>
- Local state extension service offices.

Managers often recruit volunteers to help implement SAV restoration projects. Some organizations, such as the Boys Scouts of America, have an organizational safety plan that can be applied to SAV restoration projects. Regardless of whether the volunteer group has its own approved safety plan or is covered under a project health and safety plan, managers need to ensure that volunteers are made aware of potential risks and associated health and safety requirements at the site. Finally, managers must ensure that all volunteers have completed any required work release forms. These forms should include acknowledgment of the health and safety considerations for the project site. Completion of these forms will ensure that the installation cannot be held liable for unforeseen circumstances during project execution.

Post-restoration monitoring should include extensive, detailed measurements and observations on individual plants, the entire bed, and habitat conditions. Individual planting units should initially be monitored for lateral expansion and growth. Once these begin to coalesce, you can begin to monitor the expansion of the newly created SAV bed as a whole. Quantitative observations of flowering and seed production can be used to assess the potential of the bed

Developing Data Management and QA/QC Procedures

to persist and populate adjacent areas. Monitoring habitat parameters that were measured prior to restoration will allow you to evaluate not only the effects of environmental conditions on plant survival and growth, but also the potential effects of the restoration on environmental conditions at the site.

The dimensions of individual SAV beds typically fluctuate to the extent that beds are absent in some years and very dense and productive in other years. Consequently, the presence or absence of SAV in the year following restoration is not necessarily indicative of long-term persistence or relative success. Experts believe that SAV restoration programs are only completely successful if the restored beds persist and expand in size over a period of 10 years. An ideal evaluation will involve monitoring the presence, dimensions, and relative expansion of the restored SAV bed at 1, 2, 5, and 10 years post-restoration. Regardless of relative success, the results of the project should be shared with the CBP SAV Task Group (see Mike Naylor, appendix B) to ensure that your results are included in a restoration database from which the larger restoration community can learn.

Data management and QA/QC considerations for post-monitoring are the same as those described for habitat evaluation (see chapter 3). Remember that qualitative observations and anecdotal information can also provide important insights into why a particular restoration was successful or not.

ADDITIONAL ACTIVITIES THAT SUPPORT RESTORATION

As a result of having surveyed and evaluated habitat on your installation, you may find that planting SAV is unnecessary or not justified. You can still choose to implement a project or activity that supports restoration efforts taking place elsewhere. Propagating SAV is one very worthwhile activity to consider. An SAV grow-out tank serves as a donor bed for restoration projects, reducing the need to harvest and potentially disturb or damage natural SAV beds. Outdoor grow-out tanks can be built in any shape or size, and indoor tanks can be used to maintain plant stocks over the winter for restoration projects the following year. Appendix K contains instructions for building tanks identical to those used at the USDA Plant Materials Center, the CB-NERR in Maryland (figure 4-6), and Aberdeen Proving Ground (APG), Maryland. You can modify the design and instructions to fit your particular needs or space.



Figure 4-6. Outdoor SAV tanks at CB-NERR's Otter Point Creek Reserve in Harford County, Maryland.

PHOTO: J. BORTZ, CB-NERR



Plants can be placed directly into the tanks or planted in smaller pots or other containers within the tank. For ease of moving, cleaning, or clearing, the latter approach is recommended unless the plants are being grown for the purpose of harvesting seeds. Only one species should be planted per tank to minimize contamination and simplify harvesting (Smart and Dick 1999).

Cleaning and maintaining grow-out tanks involves adding water as needed and controlling algae and mosquitoes. After the tanks are filled with water, they sometimes undergo periods of algae growth. If tanks are too large for effective hand-harvesting of unwanted algae, alum or other phosphorus-binding agents can be added to the water to inhibit algal growth (Smart and Dick 1999).

Commercial mosquito dunks (available at plant supply and home improvement stores) are used to reduce the production of mosquito larvae in the tanks. Shade cloth can be draped over the tanks during the growing season to inhibit algae growth, but sufficient light should still be available to SAV. Approximately 30% shade is recommended. Grow-out tanks generally need some degree of cleaning about twice a week, and maintaining several tanks requires about 30 to 60 minutes of labor per week. Tank maintenance is a good activity in which to involve volunteers such as Master Gardeners and Boy or Girl Scout troops.

If your facility is interested in and has space available for undertaking a more sophisticated propagation operation, guidance for initiating a micropropagation program can be obtained from Dr. Stephen Ailstock of Anne Arundel Community College or Tom Parham of the MD-DNR (see appendix C,



exhibit C-2). Micropropagation, sometimes known as tissue culture, is the process of plant multiplication in vitro, that is, growing plants from seed or small pieces of tissue under sterile conditions in a laboratory or on specially selected media. Micropropagation techniques can produce millions of plants year-round, and many SAV species are well suited for micropropagation, including wild celery, widgeon grass, sago pondweed, and redhead grass. SAV micropropagation techniques continue to be developed by MD-DNR, Dr. Ailstock, and others (Ailstock et al. 1991; Koch and Durako 1991; Bird et al. 1994; Woodhead and Bird 1998) and is a method much preferred to harvesting from natural beds to obtain large quantities of SAV planting units for restoration and research projects in the Chesapeake Bay. The MD-DNR laboratory at Ft. Meade has been used since 1998 to experiment with indoor propagation techniques for raising SAV and can serve as a model for other installations that may wish to get involved in a similar manner.



CHAPTER FIVE Outreach and Education

The success of any SAV restoration effort is contingent on many environmental factors that are beyond human control. However, a successful education and outreach effort can be achieved regardless of the outcome of restoration. The benefits of incorporating outreach and education into a comprehensive SAV program cannot be overstated.

The distinction between outreach and education is that outreach *involves* while education *informs* the local community. Outreach involves volunteers in your project and helps you accomplish your restoration goals by expanding your capabilities beyond staffing and funding limits. Educating the public about your project promotes awareness of the importance of SAV in the Chesapeake Bay and engages people to protect SAV and support its restoration.

An effective outreach and education program requires some thought and planning. Consider the following questions:

- What message do you want to convey?
- Who is the intended audience?

RECRUITING AND INVOLVING VOLUNTEERS

Sources of Volunteers

- Is your restoration site accessible to volunteers, partners, the media, and the public?

Answers to these questions will help guide the development of a suitable, effective, and efficient outreach and education plan. By implementing that plan, your project will become a collaborative effort involving you, your staff, the installation, volunteers, the local community, the media, resource managers, and researchers. The bottom line in education and outreach is partnership.

Volunteers have contributed to SAV restoration in the Chesapeake Bay for some time. Restoration project managers throughout the Bay area consider citizen involvement not only vital to the success of their projects, but also to the future health of the Bay. Volunteers have been recruited to help with SAV grow-out, planting, and monitoring. Finding people that are willing and able to help you might initially seem daunting. Fortunately, you can learn from and build on the practical lessons from other restoration projects that relied upon volunteers.

The best place to begin looking for volunteers is among existing community service groups and organizations that encourage volunteerism. Some of the following undoubtedly occur in your area:

Boy Scouts of America: Boy Scouts are typically eager to help, and the troop leaders and parents can usually assist with and ease the coordination and



oversight requirements associated with a project. Moreover, the adults can often contribute important skills and experience. Boy Scouts have been recruited to build SAV tanks and floats, prepare pots for plants, and participate in planting events. Additionally, troop members pursuing Eagle Scout badges have pursued SAV-related projects such as planning and implementing a restoration effort, building SAV tanks, and drafting designs for planting grids. The Anita C. Leight Estuary Center, CB-NERR, U.S. Army Environmental Center (USAEC), and APG have successfully recruited and involved Boy Scouts in restoration and research efforts. To locate the nearest Boy Scout Council, go to <http://www.scouting.org/nav/enter.jsp?s=xx&c=lc>.

Girl Scouts of the USA: Girl Scouts are another capable source of volunteers, and the benefits associated with partnering with Boy Scouts apply equally to Girl Scouts. Troop members in the Girl Scouts of Central Maryland region can earn a Chesapeake Bay Patch by fulfilling six activity requirements that include research, experiment, field trip, and community service categories (for a complete description go to <http://www.gscm.org/PDF/patchpackets/ChesapeakeBay.pdf>). Troops often perform badge requirement activities as a group with leader and other adult supervision. The Bronze, Silver, and Gold Awards are leadership awards that can be earned by individual scouts or a group. Each award applies to a specific age group of scouts, and all awards must culminate in a community improvement project. To locate the nearest Girl Scout Council, go to <http://www.girlscouts.org/councilfinder/>.

Gardening Groups and Chapters: Terrestrial-based volunteer gardening groups are often very eager to cross over into the aquatic environment. Master Gardeners is an excellent source of well-trained, knowledgeable volunteers that can accomplish more detailed tasks with less supervision. While they may provide fewer numbers of volunteers than scout troops, their expertise and ability to work independently sometimes make them more appropriate for particular projects. CB-NERR has had great success partnering with the Harford County chapter of Master Gardeners on several SAV research and restoration projects in Maryland. A complete listing of Master Gardener programs and chapters is available at http://www.ahs.org/master_gardeners.

Colleges and Universities: College students are a good option for more complex and technical tasks or projects, particularly during summer when their time is less restricted by school work. Students are often capable of working independently with minimal supervision, and many are eager for opportunities to gain experience in their chosen field of study, either as volunteers or interns. Student interns at the USDA Plant Materials Center have helped research SAV propagation methods. Student interns at CB-NERR have assisted with water quality monitoring, habitat evaluation, and various research projects.

Dive Clubs: Local or regional dive clubs are an excellent source of volunteers for SAV restoration projects that require SCUBA divers. Club members are often conservation minded, and club meetings make a good venue to present information on your project and importance of SAV restoration.

Public Schools: Schools are not only great source of volunteers, but partnering with schools is a means of supporting and contributing to CBP commitments to outreach and education. The USAEC and Anita C. Leight Estuary Center have successfully coordinated with Baltimore and Harford County schools. The MD-DNR “Bay Grasses in Classes” program annually coordinates students to assist with SAV grow-out and restoration efforts throughout the Chesapeake Bay (figure 5–1).



Figure 5–1. MD-DNR staff members with school children in “Grasses for the Classes” planting projects.

Watershed Organizations: Most members of local watershed organizations are already interested in improving habitats and restoring their watersheds, and you can give them that opportunity. Watershed organization meetings are a natural venue for outreach and education, complete with an eager audience. Partnering can also yield unexpected dividends in the form of gaining access to a boat or shoreline.

General Public: Recruiting volunteers from the general public can seem challenging because individual levels of interest and involvement vary so widely. The public includes many people who would like to be involved in an environmental project, but they need first to be made aware of and engaged

SAV Grow-Out

by a particular activity or event. This requires a means of recruitment and subsequent coordination and supervision. The Chesapeake Bay Foundation (CBF) “Bay Grasses for the Masses” program has recruited volunteers for restoration efforts throughout the Bay. These volunteers have helped with all aspects of restoration, including setting up plots, planting, fencing, and even monitoring. To involve the general public, you should coordinate or partner with an agency or organization with a ready pool of active volunteers, such as the CBF, ACB, MD-DNR, or CB-NERR in either Maryland or Virginia.

Volunteers have been extensively utilized to grow and propagate SAV. Examples involving Boy Scouts and student interns were noted in the previous section. In addition, the CBF and the state of Maryland each have large programs specifically for this purpose. The CBF “Bay Grasses for the Masses” program targets the general public while the MD-DNR “Bay Grasses in Classes” involves school-age children. Participants grow SAV in their homes or classrooms and return 10 to 12 weeks later with SAV in hand to participate in a designated restoration project.

Planting SAV

The same students, citizens, interns, Boy and Girl Scouts, and Master Gardeners involved in growing out SAV are frequently utilized to plant SAV in the field (figure 5-2). In fact, volunteers often derive a particular satisfaction from planting the SAV that they raised. Besides planting, volunteers can help accomplish tedious but necessary tasks associated with preparing restoration sites for planting.

Monitoring

Volunteers are utilized less frequently for monitoring than restoration activities, perhaps because project managers perceive that monitoring requires greater effort to train and supervise volunteers. In addition, effective monitoring requires minimal disturbance to the water and sediments. Consequently, the number of volunteers used at any one time or site must be strictly limited. Nevertheless, there is certainly precedence for successfully involving volunteers in monitoring SAV and habitat. The ACB has been using volunteers to collect water quality data at potential restoration sites for several years. More recently, the Anita C. Leight Estuary Center and CBF recruited volunteers to assist with post-restoration SAV monitoring at selected sites. These organizations can provide you with specific guidance on involving volunteers in your monitoring program.



Figure 5–2. Volunteer displays *V. americana* plants ready to be planted. PHOTO: J. BORTZ, CB-NERR

INVOLVING THE MEDIA

You can utilize commercial media sources to advertise events or educate the public about your project. Television, radio, and print media are often willing to announce community events at no cost and may even sponsor television promotions.

COLLABORATION AND PARTNERING

Involving commercial media in your restoration project can foster a “good neighbor” attitude between the installation and surrounding communities. Working with communications specialists in your public affairs office can help you effectively deliver your message to people on both sides of the fence. Most public affairs offices publish an installation newsletter or newspaper that provides a good medium to inform post personnel about your restoration project. Public affairs staff can also help you generate concise, effective press releases for commercial media.

Your ability to effectively restore or monitor a site is sometimes limited by a lack of expertise, resources, or staffing. These limitations can usually be overcome by collaborating with regional managers and researchers. Fortunately, expertise on SAV monitoring and restoration is abundant and widespread throughout the region. The SAV experts listed in appendix B have agreed to provide technical guidance on the environmental conditions likely to support SAV growth, as well as monitoring approaches necessary to establish habitat characteristics that define good or poor growth environments for SAV restoration projects. Additionally, oversight organizations or agencies including the Chesapeake Research Consortium, University of Maryland Center for Environmental Science (UMCES), VIMS, MD-DNR, ACB, and CBF have agreed to provide guidance on planning and conducting SAV or habitat monitoring projects. Points of contact at each organization are included in appendix B.



Your restoration goals might include formal collaboration with one or more other entities for the purpose of working together through a grant, contract, or other fiscal arrangement. Academic institutions and regional nonprofit organizations often know of regional or national funding opportunities that could expand your funding base beyond what is available from your service or the DOD (appendix J).

If you are jointly pursuing a grant from a public institution, agency, or foundation, all parties must identify specific tasks that each will undertake and must agree on the funding levels to be sought for each organization. Planning meetings should include fiscal signatories from both the installation and collaborator to ensure that each participant is authorized to receive federal funds from your service or the DOD.

If you are collaborating with another federal entity, you should be aware that funding is not transferable from one agency to another unless specific legislation exists authorizing such a transfer. Typically, if installations are authorized to receive other federal agency funds, they will also have considerable infrastructure in place for leveraging that increased support. Existing infrastructure can include subcontracts and contracts with nonfederal entities such as consulting firms. If the installation has the fiscal resources, contracting for public or private technical support must be undertaken using DOD–required procurement procedures.



Numerous partnerships are possible beyond fiscal arrangements, such as participating in subcommittees or work groups of the CBP (<http://www.chesapeakebay.net/committee.htm>) or the Chesapeake Research Consortium Freshwater SAV Partnership (<http://www.chesapeake.org/SAV/partnershiphome.html>). The latter is an assemblage of institutions, agencies, and organizations seeking increased research on the physiology and ecology of freshwater aquatic vegetation and restoration approaches for freshwater SAV. Your installation might also partner with an academic institution by providing field sites for SAV-related research. You might be able to provide resources beyond access to the site, such as sample processing space, boats, or environmental data. The benefits of this kind of partnership include research results that meet your program management needs and recognition for your program, the installation, and its natural resources.



CHAPTER SIX Case Studies

This chapter provides detailed case studies of SAV monitoring or restoration projects undertaken at Langley Air Force Base, Indian Head Naval Surface Warfare Center, and the U.S. Naval Academy and Naval Complex. These particular case studies were selected to illustrate a range of environmental conditions, partnerships, project goals, and potential outcomes. Each project utilized protocols described in this handbook. The case studies provide good examples of planning and implementing a water quality monitoring program, selecting one or more restoration sites, executing a restoration project, and lessons learned.

LANGLEY AIR FORCE
BASE

Background

Location: Back River, Virginia (76°20'W, 37°05'N)	Salinity regime: Polyhaline
Goals: Monitor water quality, evaluate historical distribution of SAV, and restore SAV	
Frequency of monitoring: Twice monthly during growing season (March to October)	
Period of monitoring: 1998–present	Number of sites: 4

The SAV program at Langley Air Force Base began in 1997 in partnership with the Alliance for the Chesapeake Bay, the National Aquarium in Baltimore (NAIB), and the Virginia Marine Resource Commission (VMRC). The program was initially funded by the DOD Legacy Resource Program. More recent sources of support have included NAIB, the Legacy-funded National Public Lands Day projects, pollution prevention grants, end-of-year funds, and a commander’s reserve account.

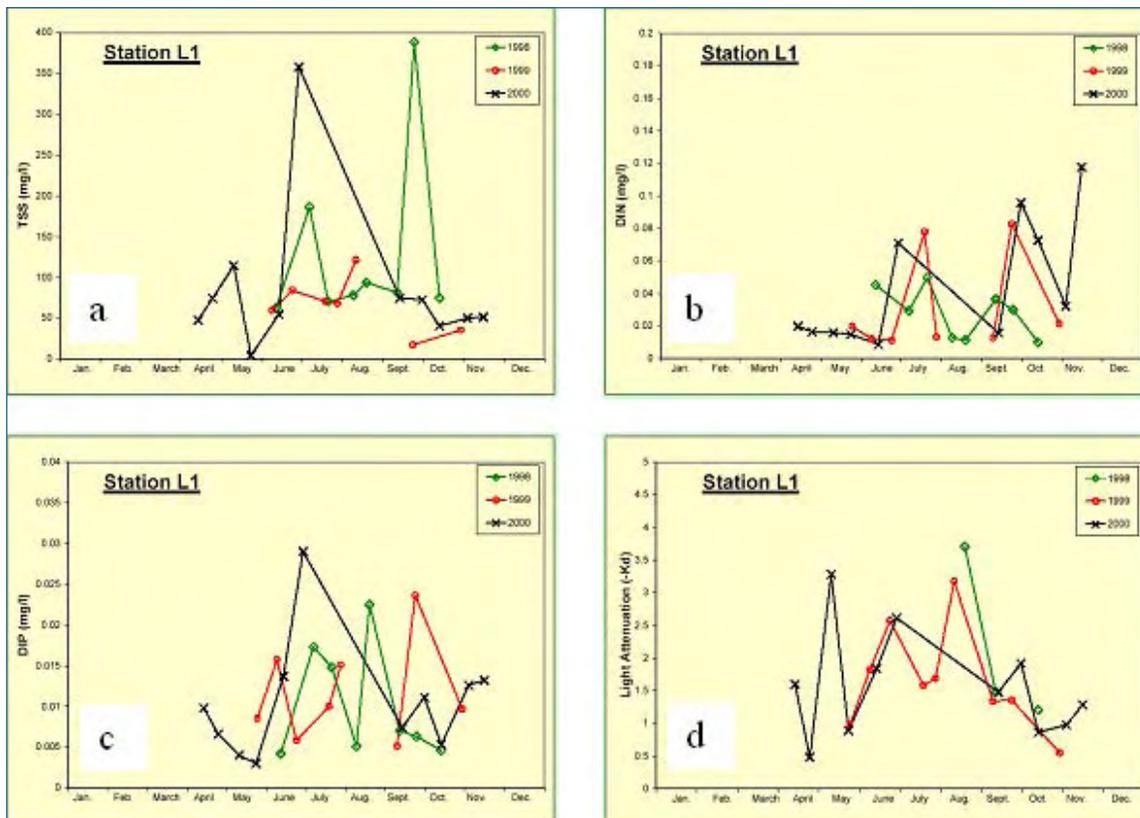
Water quality monitoring was initiated to select potential SAV restoration sites, evaluate water quality on the base, identify source pollutants, and obtain data to support the installation’s stormwater management program, including programming best management practices. Monitoring sites were established in creeks and coves in both branches of the Back River. Sites were selected based on the presence or absence of SAV (at least one currently vegetated site), historical presence of SAV, physical habitat characteristics (primarily fetch and depth), and accessibility.

Assessment and Site Selection

Base staff used a monitoring protocol developed by ACB for the Citizen Monitoring Program. Sites were monitored every 2 weeks during the growing season from 1998 to 2000. Parameters included TSS, TVS, DIN, DIP, chl-*a*, salinity, temperature, Secchi depth, and PAR at a depth of 0.5 m using LiCor light sensors. One restoration site is currently being monitored almost continuously (every 15 minutes, 24 hours per day) from April to November for salinity, dissolved oxygen, temperature, and other parameters. In 1998, SAV species composition and percent cover was determined by rake grabs in shallow (<2 m mean water depth), shoreline areas adjacent to the monitoring sites.

Water quality data were evaluated relative to the recommended habitat requirements for SAV that existed prior to the publication of Batiuk et al. 2000. Figure 6–1 summarizes annual trends in TSS, DIN, DIP, and light availability (K_d) from 1998 to 2000 at one potential site, station L1. The habitat conditions required for SAV growth at all sites were limited primarily by high concentrations of TSS. Chl-*a* concentrations exceeded the criteria for SAV growth at two sites in two different years; however, nutrient concentrations met the SAV habitat requirement at all sites and years. Sites L2 and L4 had the best water quality for SAV, and site L4 already supported a natural bed of eelgrass. Site L2 was selected for restoration in 1998 based on a combination of desirable physical characteristics and 1 year of good water quality. Restoration would proceed cautiously by first installing and evaluating test plots.

Figure 6-1.
 (a) TSS, (b) DIN,
 (c) DIP, and (d)
 light attenuation as
 indicators of water
 quality at station
 L1 near Langley Air
 Force Base (1998-
 2000). SOURCE:
 THE ACB



Restoration

In 1998, 2,600 shoots of eelgrass were planted at site L2 by DOD staff and volunteers from the general public, under the supervision of the ACB. Divers collected eelgrass by hand from a natural donor bed near Plum Tree Island Wildlife Refuge, Virginia (beds Q4 and P2, figure 6–2). Volunteers sorted plants on board a support vessel to remove detritus and other organisms and bundled them into groups of approximately 100 plants. The bundled plants were stored overnight in cooled river water. The following day, volunteer SCUBA divers from the base and the local community and military installation planted the eelgrass shoots in test plots. Other volunteers sorted the shoots in floating trays and passed them to divers as needed. The planting protocol called for overlapping the rhizomes from two shoots (two shoots per planting unit) and anchoring the plants to the substrate with a presoaked bamboo skewer (Davis and Short 1997) (figure 6–3). Planting units were evenly distributed at a density of 25 planting units per square meter (m^{-2}) (or 50 plants m^{-2}) using a spacing grid. The grid consisted of a PVC frame (1 m^{-2}) and one-quarter-inch cord strung at 25-cm intervals lengthwise and crosswise. 1 m of space was left between grids to create a checkerboard mosaic pattern (figure 6–4). The entire activity took place over a 4-hour period.

Test plots were monitored at 10 days, 4 weeks, and 7 weeks following planting. By the end of the 7-week period, mean survival was relatively high (67%), and plants exhibited increased vegetative growth and lateral expansion. By the following spring, the individual test plot grids had coalesced into larger

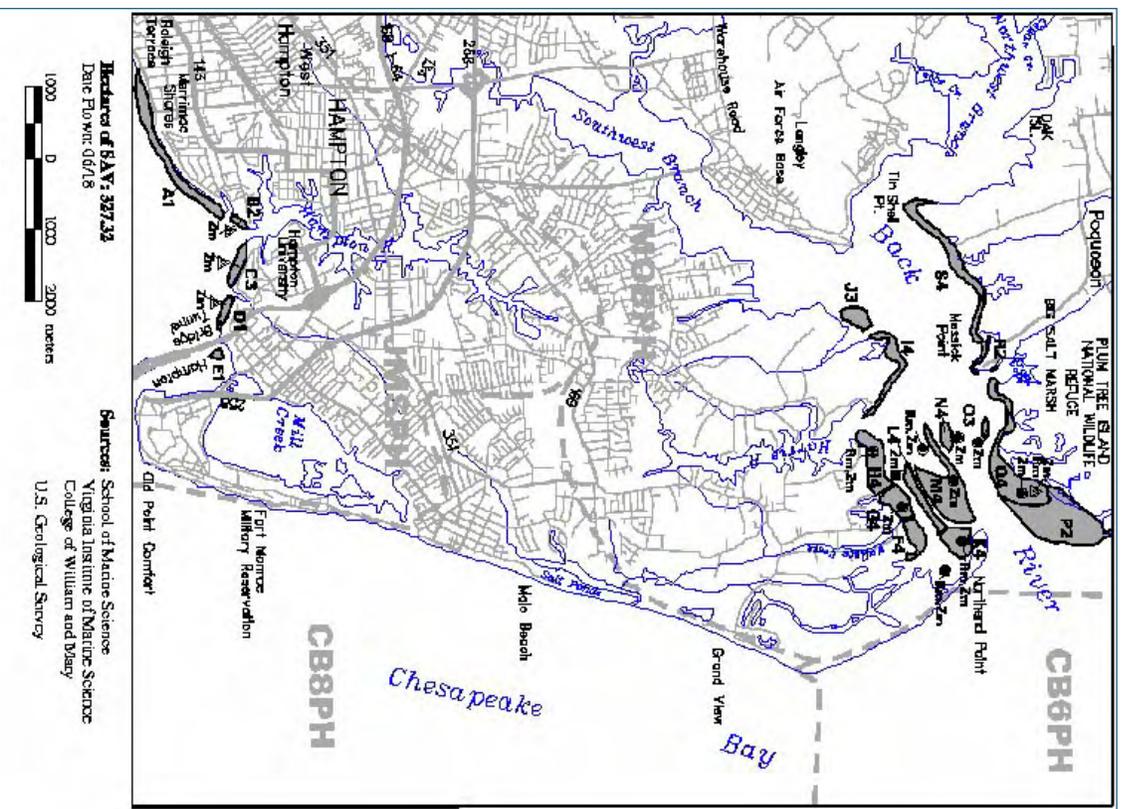


Figure 6-2. SAV planting and harvesting sites at Langley Air Force Base.
SOURCE: THE AGB

beds. The success of the test plots led to plans for a larger-scale restoration and monitoring program. In October 1999 and 2000, the ACB, in cooperation with base personnel, coordinated two plantings of approximately 5,000 plants each. Post-restoration monitoring has shown levels of plant survival, growth, and success similar to those observed for the test plots in 1998.

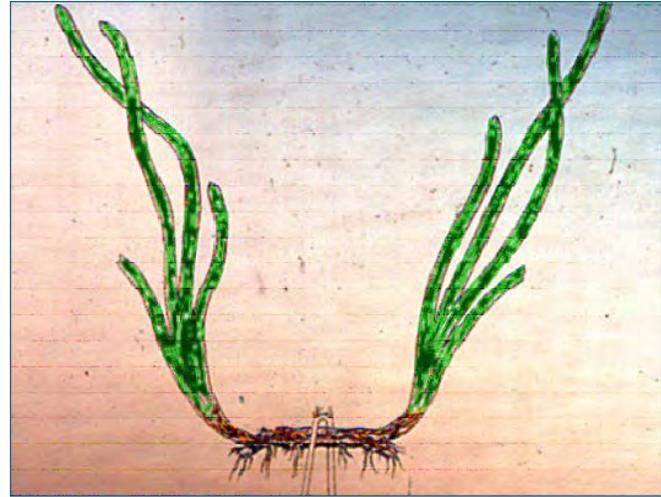


Figure 6-3. Eelgrass arrangement for the horizontal rhizome method of planting (adapted from Davis and Short 1997).
PHOTO: B. MURPHY, ACB

As of 2003, additional, smaller-scale SAV plantings have been conducted at Langley Air Force Base, and the results are pending. Water quality continues to be monitored without the assistance from ACB or Legacy Program funding. This case study illustrates that strategic and careful planning, implementation, and partnering to take advantage of regional expertise greatly enhances the likelihood of successfully restoring SAV.

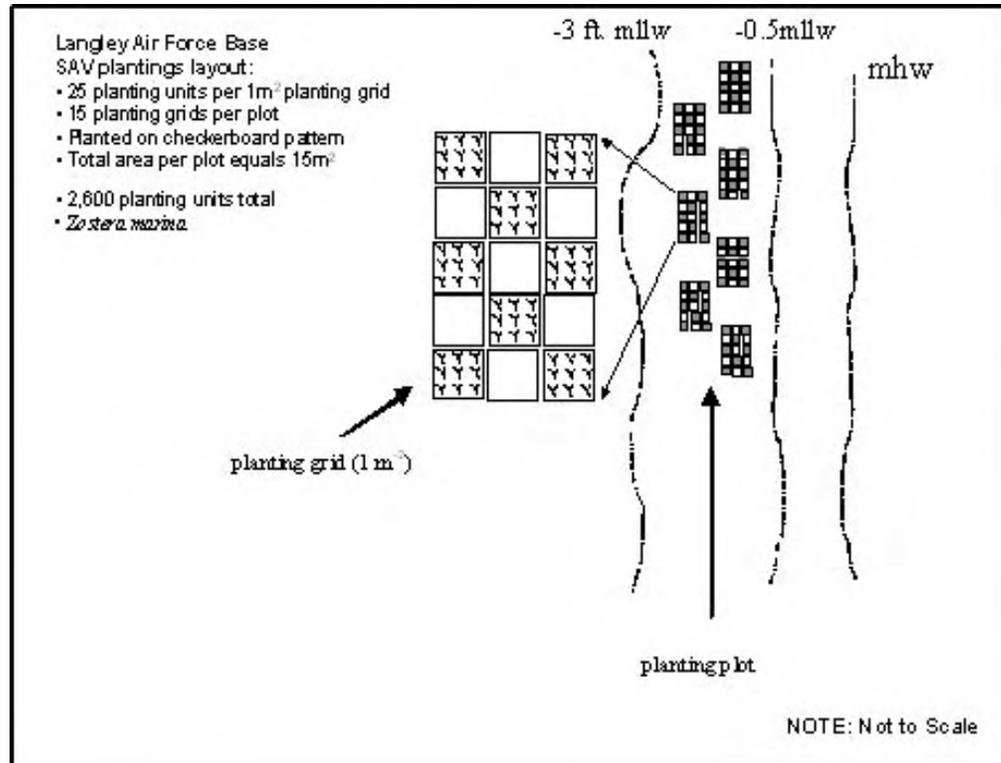


Figure 6-4. Planting grid design at Langley Air Force Base. Grid design was developed by R.J. Orth, VIMS. SOURCE: THE ACB

INDIAN HEAD NAVAL WARFARE CENTER

Background

Assessment and Site Selection

Location: Mattawoman Creek, Potomac River, MD (76°07'W, 38°32'N)	Salinity regime: Tidal fresh
Goals: Survey SAV, monitor water quality, and restore SAV	
Frequency of monitoring: Twice monthly during the growing season (April – October)	
Period of monitoring: 1997–2000	Number of sites: 6

SAV restoration at Indian Head Naval Warfare Center began in 1997 as a pilot project implemented jointly by ACB and DOD. After completing the QA/QC protocols associated with the ACB Citizen Water Monitoring Program, installation staff began collecting biweekly water samples at six monitoring stations including four vegetated and two unvegetated sites. The sites were selected by ACB primarily because of their accessibility to installation staff. Water samples were analyzed for TSS, chl-*a*, DIN, DIP, TN, and TP. DO, Secchi depth, K_d , temperature, salinity, and pH were measured in the field. Water quality data were formatted to conform to the CBP Chesapeake Information Management System database structure. Water quality was monitored from 1997 to 2000, and groundtruthing at the vegetated sites revealed hydrilla, naiads, and wild celery.

Figure 6–5 illustrates TSS, DIN, and DIP concentrations from 1997 to 2000 at one of the sites, station IH2. TSS concentrations exceeded the SAV habitat criteria of 15 mg L⁻¹ at all sites in 1 or more years (figure 6–5a). The DIN

Restoration

criterion was satisfied at all sites during all sampled years (figure 6–5b); however, DIP concentrations exceeded 0.02 mg L^{-1} criterion at three stations in 1999 (figure 6–5c). Light levels were poor at all sites in 1997 and 1998, whereas sufficient light was available for SAV at nearly all sites in 1999 and 2000. Mixed-species beds of SAV persisted in close proximity to each site despite the water quality conditions, and installation and ACB staff agreed to conduct a physical assessment of the area to identify one site for restoration. They selected a site adjacent to one of the monitoring stations based on historical presence of SAV, reasonable water quality, low wind energy, and proximity to natural beds.

In early spring 2000, 1,200 wild celery were planted in two equal-size test plots approximately 20 m apart (total area = 96 m^2). Despite heavy grazing by carp or dabbling ducks, 30% of the transplanted material survived and expanded. The site has since been colonized by nonnative and invasive hydrilla. Nevertheless, the original transplants persisted and justified continued monitoring.

A larger-scale planting (320 m^2) of 4,000 wild celery plants was undertaken in late spring 2000 using a checkerboard grid pattern (figure 6–6). The plants were obtained from Anne Arundel Community College Environmental Center and the USDA Plant Materials Center approximately 2 hours prior to transplanting and transported in coolers directly to the restoration site. The ACB recruited and trained 16 volunteers that included 8 divers (figure 6–7). Individual plants were

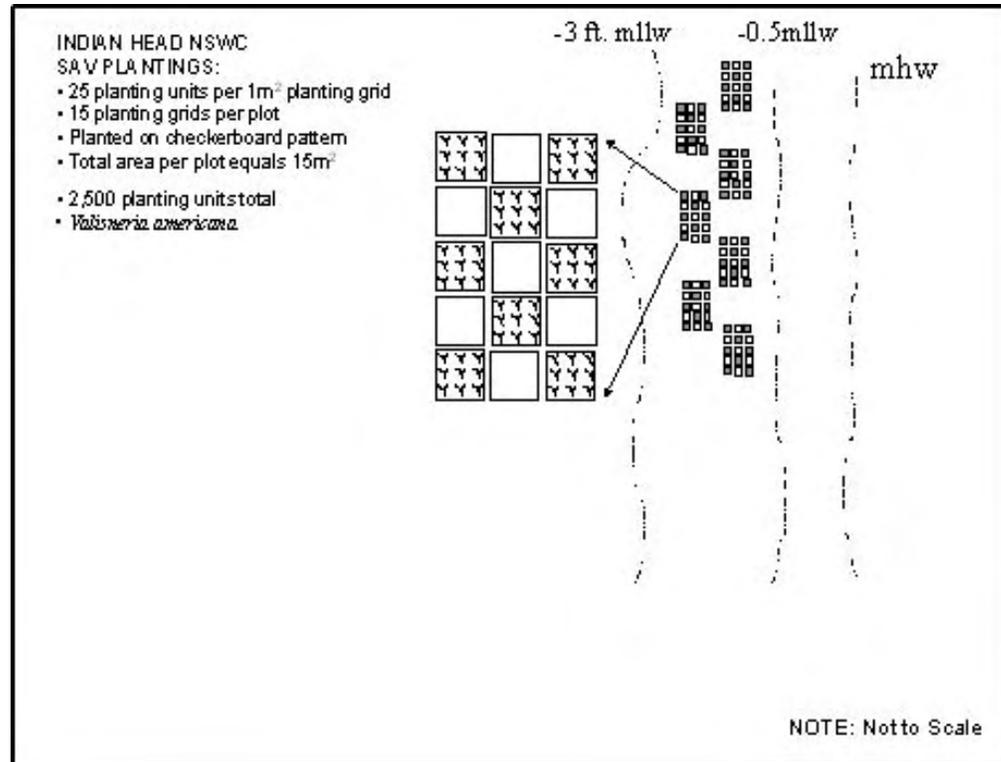


Figure 6-6. Planting design at Indian Head Naval Warfare Center (1997-2000). SOURCE: THE ACB



Figure 6-7. Planter and divers adjust a planting grid.
PHOTO: THE ACB



Figure 6-8. Volunteers building an exclusion fence.
PHOTO: B. MURPHY, THE ACB

anchored to the sediment using water-soaked bamboo skewers and planted at a density of 25 plants m^{-2} . A fence was erected around 60% of the site to protect plants from herbivores and potentially strong tidal currents. The fence consisted of orange plastic construction netting (1.3 m in height) attached to wooden stakes every 2 m. The remainder (40%) of the site was intentionally unprotected to test for any difference between fenced and unfenced plots (figure 6-8).

The larger site was monitored at 3 weeks, 3 months, and 1 year following planting. Mean plant survival within the exclusion fence was 55%, compared to 20% outside the fence. Unprotected plants were most often severed

approximately 12 to 15 cm above the substrate, indicating that the plants had been grazed by dabbling ducks. Hydrilla colonized the larger restoration site as it had done in the test plot.

The restoration sites have not been monitored since early 2001 because of limited funding. At last check, wild celery beds were present at widely varying densities. Installation staff has continued to assess water quality at one monitoring station; however, the future of SAV restoration and water quality monitoring at the Indian Head Naval Warfare Center is uncertain.

U.S. NAVAL ACADEMY

Location: Severn River, Maryland (76°30W', 38°55'N)	Salinity regime: Mesohaline
Goals: Monitor water quality and restore SAV	
Frequency of monitoring: Twice monthly during the growing season	
Period of monitoring: 1997–2000 (some monitoring in subsequent years)	Number of sites: 4

Background

What follows is a brief description of a SAV restoration project on the Severn River in Annapolis, Maryland (figure 6–9). Water quality monitoring was initiated in 1997 to select among 4 potential restoration sites.

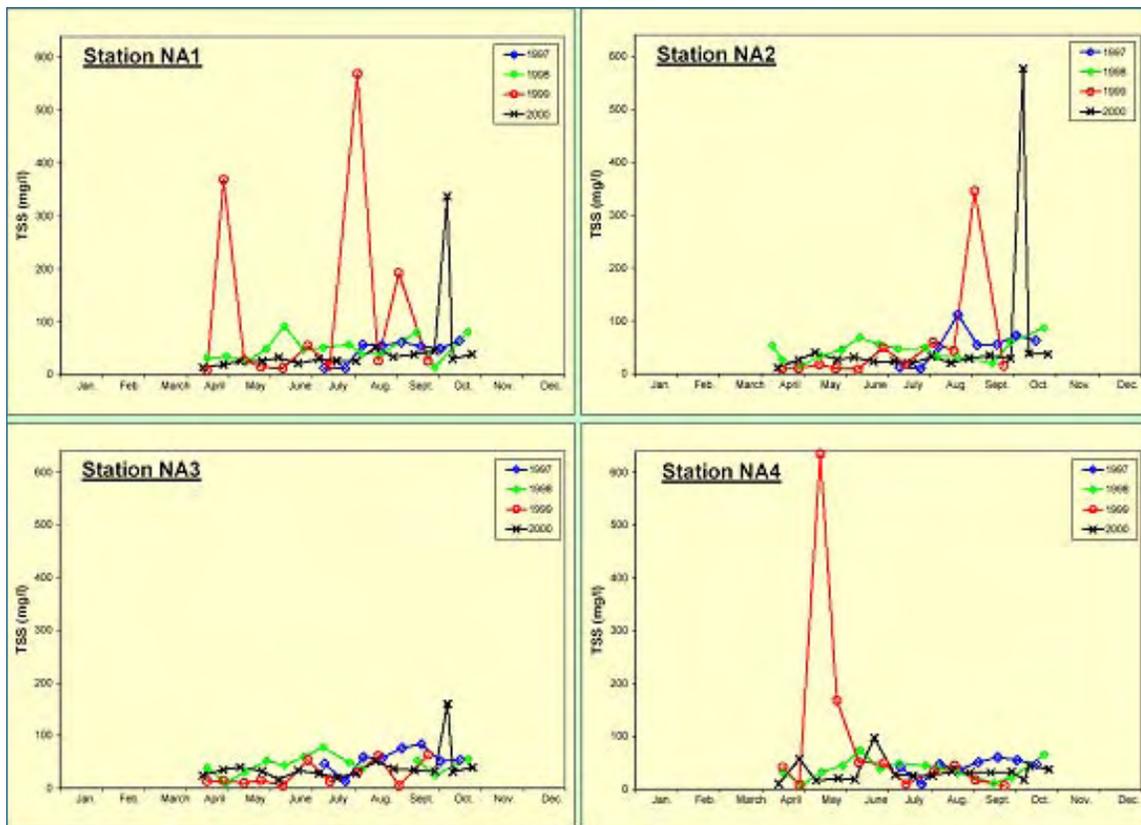
Assessment

Water quality did not meet all of the SAV habitat requirements at any of the four sites. TSS concentrations were particularly high (figure 6–10), and chl-*a* concentrations also exceeded the level required for SAV. Despite marginal water quality, the Academy and ACB elected to initiate restoration at a site on Seabee Beach, based on suitable sediments, low wave energy, and the best water quality among the four potential sites. Moreover, the site already supported small patches of widgeon grass (*R. maritima*) and contained horned pondweed (*Z. palustris*) in some years.

Planting

A combination of widgeon grass, sago pondweed, and redhead-grass were test-planted during spring 1999. The sago pondweed and redhead-grass, grown

Figure 6–10. TSS concentrations for the four sites at the U.S. Naval Academy (1997–2000). SOURCE: THE ACB



at Anne Arundel Community College, were transplanted directly into the sediments by hand. The widgeon grass had been grown on coconut-fiber mats at the UMCES Horn Point Laboratory. The plants were anchored to the bottom with biodegradable bamboo skewers (Davis and Short 1997). The transplanted sago pondweed and redhead-grass were not present at the end of the growing season. During the same period, the widgeon grass had survived and expanded into dense, healthy beds and had produced flowers. However, the beds did not persist the following spring.

It was decided that additional restoration efforts should not be pursued unless monitoring reveals significant improvements in water quality, or until measures are taken to reduce TSS concentrations. Particularly high TSS levels at one site may be attributable to sediment resuspension due to boat traffic and wind. The construction of an offshore oyster reef is one measure that could reduce near-shore wave energy and particle resuspension. Oysters could provide additional benefits to the site by improving water quality as a result of their filter-feeding activity (Newell and Koch 2004).

APPENDIX A

SAV Activities at DOD Installations on the Chesapeake Bay and Its Tidal Tributaries

Service, Installation	Funding Source	Ground-truthing	Water Quality	Education and Outreach	SAV Restoration/Planting
Army					
Aberdeen Proving Ground	AEC, APG, DSHE, ARL	1996–2005	1996–2005	Yes	Yes; 1996–1999 (sago pondweed, wild celery, and redhead grass), some success; summer 2004 (water stargrass, wild celery, redhead grass, common waterweed)
Blossom Point Test Facility	DOD Legacy, ARL	1997–2003	1999–2004	No	Yes; abundant SAV, but some invasive (wild celery, Eurasian watermilfoil); restoration project planned for 2005
Fort Eustis	DOD Legacy	Limited	1998–2000	No	Yes; May and October 1999 (widgeon grass, sago pondweed), some success

Service, Installation	Funding Source	Ground-truthing	Water Quality	Education and Outreach	SAV Restoration/Planting
Fort Monroe	DOD Legacy	Limited	1998–2003	Limited	Yes; October 1998 (eelgrass), unsuccessful; summer 2003 (widgeon grass seeds), TBD
Fort McNair	None	No	No	No	No
Fort Belvoir	USACE	2004	2004	No	Planned for 2006 (species TBD)
Air Force					
Langley Air Force Base	DOD Legacy NAIB, NPL, PP, CRA, EYF	1996–1999	1998–2003	Yes	Yes; test plot 1998–1999, full planting October 2001–2002 (eelgrass), successful
Bolling Air Force Base	DOD Legacy	No	1999	No	No; resources, proximity of natural beds
Navy					
Naval Air Station, Patuxent River	NRI	1997–2003	2000–2002	Yes	No; plenty of SAV (horned pondweed, widgeon grass)
Naval Surface Warfare Center, Dahlgren	DOD Legacy, NRI	No	1998–2003	Limited	Yes; 2000 (redhead grass), unsuccessful
Naval Surface Warfare Center, Indian Head	DOD Legacy, NRI	Yes	1996–2003	Limited	Yes; May 2000 (wild celery), successful

Service, Installation	Funding Source	Ground-truthing	Water Quality	Education and Outreach	SAV Restoration/Planting
Solomon's Naval Annex	NRI, agriculture, CBT	No	No	No	Yes; 1999–2000 (widgeon grass, eelgrass, sago pondweed), unsuccessful
Annapolis Naval Academy	DOD Legacy, other sources	1995, 1997–2003	1997–2003	Yes	Yes; fall 1998 and summer 1999 (redhead grass, widgeon grass, sago pondweed), unsuccessful
Navy Region Mid Atlantic – Yorktown	DOD Legacy	No	1999–2000	No	No; water quality not conducive
Navy Region Mid Atlantic – Little Creek	DOD Legacy	Limited	1997–2001	Yes	Yes; October 2000 (eelgrass and widgeon grass), successful

Note:

AEC = Army Environmental Center
 APG = Aberdeen Proving Ground
 ARL = Army Research Lab
 USACE = U.S. Army Corps of Engineers

CBT = Chesapeake Bay Trust
 CRF = Commander Reserve Fund
 DSHE = Directorate of Safety, Health, and the Environment
 EYF = End of Year Funds

NAIB = National Aquarium in Baltimore
 NP = National Public Lands
 NRI = Natural Resource Installation
 PP = Pollution prevention grants
 TBD = To Be Determined

APPENDIX B

Technical Points of Contact for SAV in the Chesapeake Bay

Dr. Stephen Ailstock

Anne Arundel Community College, Arnold, MD

E-mail: smailstock@aacc.edu

Areas of expertise: Restoration (invasive species management, propagation of wild celery, widgeon grass, sago pondweed, and redhead grass)

Mr. Ben Anderson

Division of Water Resources, Watershed Assessment Branch, Delaware Department of Natural Resources, Dover, DE

E-mail: Bennett.Anderson@state.de.us

Areas of expertise: Surveys and groundtruthing; water quality monitoring; restoration

Dr. Peter Bergstrom

NOAA Chesapeake Bay Office, Annapolis, MD

E-mail: peter.bergstrom@noaa.gov

Areas of expertise: Surveys and groundtruthing; restoration

Ms. Jill Bieri

NOAA Chesapeake Bay Office

E-mail: jbieri@noaa.gov

Areas of expertise: Outreach and education

Ms. Julie Bortz

Chesapeake Bay National Estuarine Research
Reserve, Annapolis, MD

E-mail: jbortz@dnr.state.md.us

Areas of expertise: Surveys and groundtruthing;
water quality monitoring; restoration (test
plots, multispecies plantings, SAV floats); tidal
freshwater species

Dr. David Burdick

University of New Hampshire, Durham, NH

E-mail: dburdick@cisunix.unh.edu

Areas of expertise: Water quality monitoring
(land-use impacts); restoration; post-restoration
evaluation

Ms. Andrea Hardy Campo

Chesapeake Bay National Estuarine Research
Reserve, Annapolis, MD

E-mail: ahardycampo@dnr.state.md.us

Areas of expertise: Restoration (test plots and SAV
floats); outreach and education

Ms. Marcy Damon

Chesapeake Bay Foundation, Annapolis, MD

E-mail: mdamon@cbf.org

Areas of expertise: Outreach and education;
restoration

Dr. Ryan Davis

Exponent, Inc., Albany, NY

E-mail: rdavis@exponent.com

Areas of expertise: Water quality monitoring;
restoration (methods development and training);
post-restoration evaluation.

Dr. Bill Dennison

University of Maryland Center for Environmental
Science, Cambridge, MD

E-mail: dennison@ca.umces.edu

Areas of expertise: Habitat evaluation (health
bioindicators)

Dr. Katia Engelhardt

University of Maryland Center for Environmental Science, Appalachian Laboratory, Frostburg, MD

E-mail: engelhardt@al.umces.edu

Areas of expertise: Restoration (diversity); post-restoration evaluation; freshwater and invasive species

Mr. Bob Finton

Chesapeake Bay National Estuarine Research Reserve, Annapolis, MD

E-mail: rfinton@dnr.state.md.us

Areas of expertise: Outreach and education

Dr. Mark Fonseca

NOAA, Beaufort Laboratory, Beaufort, NC

E-mail: mark.fonseca@noaa.gov

Areas of expertise: Restoration; post-restoration evaluation; polyhaline species

Mr. Jerold Griswold

U.S. Department of Agriculture, Natural Resources Conservation Service, Annapolis, MD

E-mail: Griswold.jerry@md.nrcs.usda.gov

Areas of expertise: Restoration (native plant and seed stocks, propagation)

Dr. Jud Kenworthy

NOAA, Beaufort Laboratory, Beaufort, NC

E-mail: Jud.Kenworthy@noaa.gov

Areas of expertise: Restoration; post-restoration evaluation; polyhaline species

Dr. Evamaria W. Koch

University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, MD

E-mail: koch@hpl.umces.edu

Areas of expertise: Habitat evaluation (hydrodynamics); water quality monitoring; restoration (propagation of widgeon grass, multitrophic level projects); post-restoration evaluation

Dr. Stan Kollar

Harford Community College, Bel Air, MD

E-mail: skollar@harford.edu

Areas of expertise: Restoration (propagation);
freshwater species

Dr. Robert Magnien

NOAA, National Ocean Service Center for Sponsored Coastal Ocean Research, Annapolis, MD

E-mail: rob.magnien@noaa.gov

Areas of expertise: Water quality monitoring
(eutrophication impacts)

Dr. Ken Moore

Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA

E-mail: moore@vims.edu

Areas of expertise: Surveys and groundtruthing;
water quality monitoring (human impacts, habitat requirements); restoration (transplanting and use of seed); tidal freshwater and polyhaline species

Mr. Bob Murphy

Alliance for the Chesapeake Bay, Baltimore, MD.

E-mail: bmurphy@acb-online.org

Areas of expertise: Water quality monitoring;
restoration (methods development, multitrophic level projects); outreach and education; tidal species

Dr. Laura Murray

University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge, MD

E-mail: murray@hpl.umces.edu

Areas of expertise: Outreach and education;
restoration (widgeon grass and redhead grass)

Mr. Mike Naylor

Maryland Department of Natural Resources,
Annapolis, MD

E-mail: mnaylor@dnr.state.md.us

Areas of expertise: Surveys and groundtruthing
(GIS mapping, historical distributions); water
quality monitoring (habitat requirements);
restoration (Chesapeake Bay targets); outreach
and education

Dr. Hilary Neckles

U.S. Geological Survey, Augusta, ME

E-mail: hilary_neckles@usgs.gov

Areas of expertise: Habitat evaluation (human
impacts on eelgrass)

Dr. Roger Newell

University of Maryland Center for Environmental
Science, Horn Point Laboratory, Annapolis, MD

E-mail: newell@hpl.umces.edu

Areas of expertise: Restoration (multitrophic level
projects)

Mr. Charles Norman

Anne Arundel Community College, Arnold, MD

E-mail: cmnorman@aacc.edu

Areas of expertise: Restoration (propagation)

Dr. Robert J. Orth

Virginia Institute of Marine Science, College of
William & Mary, Gloucester Point, VA

E-mail: jjorth@vims.edu

Areas of expertise: Surveys and groundtruthing
(GIS mapping, aerial photography, historical
distributions); water quality monitoring
(growth requirements); restoration (methods
development); post-restoration evaluation;
polyhaline species

Mr. Glenn Page

National Aquarium in Baltimore, Baltimore, MD

E-mail: gpage.aqua.org

Areas of expertise: Restoration; outreach and
education

Ms. Nancy Rybicki

U.S. Geological Survey, Reston, VA

E-mail: nrybicki@usgs.gov

Areas of expertise: Habitat evaluation (hydrodynamics, diversity and abundance); water quality monitoring (growth requirements) restoration (Chesapeake Bay targets); tidal freshwater species

Dr. Frederick Short

University of New Hampshire, Durham, NH

E-mail: fred.short@unh.edu

Areas of expertise: Habitat evaluation; restoration (methods development); polyhaline species

Dr. Michael Smart

U.S. Army Corps of Engineers, Engineer Research and Development Center, Hanover, NH

E-mail: msmart@gte.net

Areas of expertise: Restoration (propagation, methods development); freshwater and estuarine species

Dr. J. Court Stevenson

University of Maryland Center for Environmental Science, Horn Point Laboratory, Annapolis, MD

E-mail: court@hpl.umces.edu

Areas of expertise: Water quality monitoring; habitat evaluation (human and natural impacts, historical distributions); restoration

Dr. Chris Tanner

St. Mary's College of Maryland, St. Mary's City, MD

E-mail: cetanner@smcm.edu

Areas of expertise: Restoration; oligo- and polyhaline species; disease

Ms. Rebecca Thur

Chesapeake Research Consortium Freshwater SAV Partnership, Edgewater, MD

E-mail: thurb@si.edu

Areas of expertise: tidal freshwater SAV restoration

Mr. David J. Wilcox

Virginia Institute of Marine Science, College of
William & Mary, Gloucester Point, VA

E-mail: dwilcox@vims.edu

Areas of expertise: Surveys and groundtruthing
(GIS mapping, aerial photography)

APPENDIX C Equipment and Suppliers

This appendix describes various types of equipment used in SAV fieldwork. Exhibit C-1 lists suppliers who carry these types of equipment. Exhibit C-2 lists distributors who carry SAV plant stock and seeds.

Black/white Secchi Disk with Weighted Line: A Secchi disk is used to determine the depth to which light penetrates in the water column (Secchi depth). Secchi depth is used to estimate the light attenuation coefficient, or K_d ($K_d = 1.45/\text{Secchi depth}$).

Fieldmaster Water Bottle Kit: The Fieldmaster water bottle kit contains a horizontal water sampler, line and weight to measure depth, and a carrying case.

Filtering Apparatus: Nalgene filter units (500 (milliliter) mL or 1000 mL) are used to filter water samples for prior to analysis of parameters such as chl-*a*, TSS, and dissolved nutrients.

General Sampling Equipment: Some general field items you may need include aluminum foil, plastic bags, coolers, ice packs, batteries, labeling tape, permanent markers, sealable plastic bags (such as Ziploc® brand), pencils, and waterproof field notebooks.

Exhibit C-1. Field Equipment Suppliers

Air Photographics

Web Site: <http://www.airphotographics.com>

E-mail: info@airphotographics.com

Phone: (304) 263-6976, (800) 624-8993

Ben Meadows

Web Site: <http://www.benmeadows.com>

E-mail: mail@benmeadows.com

Phone: (800) 241-6401

Fisher Scientific

Web Site: <https://www1.fishersci.com/index.jsp>

E-mail: none

Phone: (800) 766-7000

Forestry Suppliers, Inc.

Web Site: <http://www.forestry-suppliers.com/index1.asp>

E-mail: cs@forestry-suppliers.com

Phone: (800) 752-8460

VWR Scientific

Web Site: <http://www.vwrsp.com/index.cgi>

E-mail: solutions@vwr.com

Phone: (800) 932-5000

GPS Unit: A GPS unit is required to accurately determine location (or coordinates) of sampling sites, SAV bed boundaries, sampling routes, and other geographical data. Examples include the Garmin eTrex, Venture, and Vista. The unit should have Wide Area Augmentation System (WAAS) capability for greater resolution and accuracy. Data can be uploaded and downloaded between the

GPS unit and a computer using Mapsource software (United States Roads and Recreation CD-ROM).

Li-Cor Light Meter: The Li-Cor meter is a spherical underwater sensor and datalogger that measures light or (PAR) in the water column. K_d is calculated from light readings at two depths using the Lambert-Beer equation:

$$K_d = \frac{\ln \frac{I_z}{I_o}}{Z}$$

where K_d = light attenuation coefficient (m^{-1}), I_z = light (μmol photons $m^{-2} s^{-1}$) at depth Z (m), and I_o = light (μmol photons $m^{-2} s^{-1}$) at a depth of 0 meters (just below the water surface). The Li-Cor meter can also be programmed to continuously record light over time at a set location, but the sensor needs to be cleaned on a daily basis because of fouling.

pH Meter: A pH meter should be waterproof, autocalibrating (for temperature), and accurate to +/- 0.1 pH units. An example is the Oakton Waterproof pH Tester 2.

pH Buffers: A pH meter needs to be periodically calibrated using buffer solutions of pH 4.0, 7.0, and 10.0. Disposable buffer pouches are available; however, bulk (500 mL) bottles of solution are a more environmentally friendly choice.

Pump: A hand pump with pressure gauge, such as the Mityvac Superpump, is used to draw a vacuum through the filtering apparatus.

SAV Species Identification Guide: There are a number of different guidebooks available. *Common Marsh, Underwater, and Floating-Leaved Plants of the United States and Canada* (Hotchkiss 1972) is a good comprehensive guide

Exhibit C-2. Plant Stock and Seed Distributors

Anne Arundel Community College

Web Site: www2.aacc.cc.md.us/environmental_center/submergedwetlandsplants.html

Contact: Dr. Stephen Ailstock

E-mail: smailstock@aacc.edu

Phone: (410) 777-2230

Kollar Environmental Associates and Nursery

Web site: <http://www.kollarnursery.com>

Contact: Dr. Stan Kollar

E-mail: skollar@harford.edu

Phone: (410) 836-0500

Maryland Department of Natural Resources, Piney Point Laboratory

Web Site: http://mddnr.chesapeakebay.net/savrrc/plant_source_information.html

Contact: Tom Parham

E-mail: tparham@dnr.state.md.us

Phone: (410) 260-8630

Seagrass Recovery, Inc.

Web Site: <http://www.seagrassrecovery.com>

Contact: Jim Anderson, President

E-mail: JAnderson@SeagrassRecovery.com

Phone: (813) 641-6763

Exhibit C-2. Plant Stock and Seed Distributors (contd.)

University of Maryland Center for Environmental Science, Horn Point Laboratory

Web Site: <http://www.hpl.umces.edu>

Contact: Dr. Evamaria W. Koch

E-mail: koch@hpl.umces.edu

Phone: (410) 221-8418

United States Department of Agriculture Plant Materials Center

Web Site: <http://plant-materials.nrcs.usda.gov>

Contact: John M. Englert

E-mail: John.Englert@md.usda.gov

Phone: (301) 504-8175

Wayfarer Nursery and Supply, Inc.

Web Site: <http://www.wayfarernursery.com>

Contact: Jayson Meyers

E-mail: info@wayfarernursery.com

Phone: (410) 584-1022

for identifying SAV species and distinguishing between true SAV and non-SAV aquatic plants. Other resources include *Chesapeake Bay Submerged Aquatic Vegetation Identification Guide* (David and Reel 2001), *Chesapeake Bay Foundation Guide to Underwater Grasses* (http://www.cbf.org/site/DocServer/Guide_to_Underwater_Grasses.pdf?docID=116), *Field Guide to the Submerged Aquatic Vegetation of the Chesapeake Bay* (Hurley 1992), and *Underwater Grasses in Chesapeake Bay & Mid-Atlantic Coastal Waters: Guide to Identifying*

Submerged Aquatic Vegetation (Bergstrom et al. 2005). In addition, several on-line species identification keys are available, including one maintained by MD-DNR (<http://www.dnr.state.md.us/bay/sav/key/index.asp>) and another by the Chesapeake Research Consortium Freshwater SAV Partnership (<http://www.chesapeake.org/SAV/fwsav.html>).

Snorkel and Mask and/or SCUBA Equipment: Snorkeling is a good way to survey SAV and habitat, particularly in shallow (<3 m), clear water, whereas SCUBA gear is often required in deeper (>3 m) areas. Snorkeling or diving can be used in lieu of or in addition to an underwater camera to determine SAV presence or absence and species composition. SCUBA diving requires considerable equipment and training, but may be vital if a project involves more intensive field methods such as transect sampling and biomass determination.

Steel-Toothed Rake: A simple, steel garden rake with a long (≥ 6 ft) handle is used to sample SAV and determine percent cover in highly turbid, shallow (<1.5 m) water (Jessen and Lound 1962). For additional recommendations, visit <http://noaa.chesapeakebay.net/sav.htm>.

Underwater Camera: The Aqua-Vu or another comparable camera is recommended for documenting SAV in relatively deep (>2 m), clear water. A cable attaches the Aqua-Vu to a small, black and white monitor that is typically mounted on a flat surface in a boat. Underwater cameras have limited utility in



highly turbid or low-light conditions. The Aqua-Vu is available on-line at <http://www.aquavu.com/compare.html>.

View Scope: A view scope is often used to monitor the success and health of transplanted SAV. Its utility is limited to very shallow (<1 m) sites where plants are not visible from above the water surface.

Water Collection Bottles: Wide-mouth Nalgene bottles (500 ml) are used to hold water samples for subsequent analysis. Clear bottles are recommended if you intend to reuse the containers. Before reusing, the bottles should be acid-washed (10% HCL solution) and rinsed three to six times with distilled or deionized water. Any analytical laboratory should be able to provide you with recommended procedures.

Water Quality Meter: A wide variety of handheld, multifunction water quality meters are available from YSI, Hach, and other manufacturers. An example is the YSI 85 handheld meter. It measures DO, salinity, conductivity, and temperature. It is available with various options, including cable length (10 ft, 25 ft, 50 ft, or 100 ft), a waterproof carrying case, and additional cap membranes and fill solution.

APPENDIX D

Sample SAV Survey Form

Exhibit D–1. SAV Species Abbreviations

Zm	<i>Zostera marina</i> (eelgrass)	Nm	<i>Najas minor</i> (spiny naiad)
Rm	<i>Ruppia maritima</i> (widgeon grass)	Nt	<i>Nitella</i> sp. (muskgrass)
C	<i>Chara</i> sp. (muskgrass)	Pcr	<i>Potamogeton crispus</i> (curly pondweed)
Cd	<i>Ceratophyllum demersum</i> (coontail)	Pe	<i>Potamogeton epihydrus</i> (leafy pondweed)
Cl	<i>Callitriche</i> sp. (water-starwort)	Pn	<i>Potamogeton nodosus</i>
Ec	<i>Elodea canadensis</i> (common elodea)	Ppc	<i>Potamogeton pectinatus</i> (sago pondweed, now known as <i>Stuckenia pectinata</i>)
Ed	<i>Egeria densa</i> (water-weed)	Ppf	<i>Potamogeton perfoliatus</i> (redhead-grass)
Hd	<i>Heteranthera dubia</i> (water stargrass)	Ppu	<i>Potamogeton pusillus</i> (slender pondweed)
Hv	<i>Hydrilla verticillata</i> (hydrilla)	S	<i>Sparganium</i> sp. (bureed)
Ms	<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)	Tn	<i>Trapa natans</i> (water chestnut)
N	<i>Najas</i> sp. (naiad)	Va	<i>Vallisneria americana</i> (wild celery)
Nfl	<i>Najas flexilis</i> (northern naiad)	Zp	<i>Zannichellia palustris</i> (horned pondweed)
Ngr	<i>Najas gracillima</i> (slender naiad)	U	Unknown species
Ngu	<i>Najas guadalupensis</i> (southern naiad)		

SAMPLE SAV SURVEY FORM (Adapted from USEPA 1993)

Name:				Telephone:			
Address:			City:			State:	Zip:
SURVEY SITE							
Name of Site/Map/Quadrangle #:			GPS Location:				
Date:			Time:	a.m. or p.m.		Water Depth:	m
Plants Surveyed From:	Boat	Shore	Pier	Other_____			
Water Conditions:	Clear	Murky	Other_____				
SURVEY							
For each plant bed, verify location and size, estimate SAV density, and identify plants present using a field guide. Write "no plants" for marked beds/areas without any SAV. With a pencil, outline the position of new beds and identify them by number directly on a map.							
Bed Name:			Approximate Density:			Species Present:	
Comments (bed location and size changes, density or species changes since last sighting, weather and water conditions, problems, etc.):							
Bed Name:			Approximate Density:			Species Present:	
Comments (bed location and size changes, density or species changes since last sighting, weather and water conditions, problems, etc.):							
Send completed forms to the SAV Survey Coordinator							

APPENDIX E

Groundtruthing Protocol

TASK 1: CHECK WEATHER CONDITIONS

TASK 2: CHECK EQUIPMENT

The following protocol was adapted from USEPA (1993) and NOAA (<http://noaa.chesapeakebay.net/sav.htm>).

Listen to forecast and observe current conditions before going into the field, especially if traveling by boat.

- Boat with required U.S. Coast Guard items.
- Maps
- GPS unit or compass
- Weighted and calibrated line or calibrated measuring pole to measure water depth
- Secchi disk
- Measured lines/tapes if you are doing transect work
- SAV field identification guides and species abbreviation list
- Plastic sealable sample bags (such as the Ziploc® brand)

(checklist continues on next page)

**TASK 3: LOCATE
SAV BEDS****TASK 4: SURVEY
SAV BEDS**

- Permanent markers for labeling bags and pencils for completing data sheets
- Survey data sheets
- Clipboards
- Rakes
- Mask and snorkel or SCUBA equipment
- Footwear and clothes that can get wet, chest waders, or wet suits (remember to protect yourself from sea nettles)
- Polarized sunglasses
- View scope or underwater camera
- Sunscreen and drinking water.

Accessing survey sites may involve a combination of walking, wading, swimming, and boating. A canoe, kayak, john boat, or skiff with outboard motor is usually required for most surveys. See <http://noaa.chesapeakebay.net/sav.htm> for a discussion of the pros and cons of various watercraft.

The best conditions for surveying SAV include mostly sunny weather, clear water conditions, and within 2 hours of low tide. Surveys are conducted most efficiently when SAV beds can be located visually rather than by raking.

- 
- ❑ Note the location and extent of each SAV bed relative to the shoreline or other notable landscape features. Compare the current bed locations to their previously noted map positions.
 - ❑ Record any new beds and note any significant changes in the location of existing beds on the data sheet and a map.
 - ❑ Complete preliminary information fields on the data sheet (surveyor's name, address, telephone number, site name/code).
 - ❑ Move around beds in a predetermined pattern (zig-zag or along a depth-contour). Visually estimate bed density and record with a numeric code (none = 0, <5% = 1, 10% to 40% = 2, 40% to 70% = 3, 70% to 100% = 4). Record information on the general appearance of the plants and the size of the bed. Information and associated maps from previous survey visits are helpful for determining whether a bed is growing and thickening or shrinking and becoming sparser. Record the general water conditions such as water clarity (clear/murky/other), surface debris, oil slicks, fish kills, peculiar odors, boat traffic, and waterfowl. If surveying SAV along regular transects (that is, at intervals of 20 to 50 ft), record the water depth, GPS location, and SAV species at each point along the transect.

(checklist continues on next page)

- ❑ Sample and identify SAV species using rake grabs, view scopes, or cameras, or by snorkeling, diving, or wading. Some species, such as eelgrass, are not readily visible from a boat and must be surveyed by snorkeling or SCUBA. Avoid digging rakes or other tools into the sediment to minimize damage to roots and rhizomes.
- ❑ Record SAV species by name or abbreviation on the survey form. Use field guides to identify SAV species. Note that true SAV is not emergent, except for the flowers of a few species (for example, redhead grass). Do not record terrestrial plants or floating or emergent plants, with the exception of water chestnut (*T. natans*), that may be growing underwater during a very high tide or in the spring. Emergent water chestnut (*T. natans*) is recorded because it is highly invasive. Unknown specimens should be placed in a plastic bag labeled with site information. Record the site location in permanent marker on the outside of the bag, and in pencil on a waterproof paper label placed inside the bag. Bagged samples will last for 1 to 2 weeks in a refrigerator if the water is regularly changed.
- ❑ Because the peak growing season differs among SAV species, two or more visits per year are recommended to find all species present and to ensure accurate determination of presence/absence. If time permits, look for SAV on shoals that are marked on maps or navigation charts.

**TASK 5: ORGANIZE
AND SHARE YOUR
DATA**

Review all data sheets immediately upon returning from the field to add clarifying notes, ensure that all data fields have been completed, and correct any errors. Identify any unknown species using a microscope or by contacting an expert. GPS locations (degrees and decimal minutes) and SAV species for each bed can be entered on a spreadsheet and imported directly into GIS software. Use the NAD83 or WGS84 map datum if available. You should share your data, including anecdotal observations, with VIMS for verification. Send your data to VIMS by the fall of the year in which it was collected for possible inclusion in VIMS annual SAV distribution report.



APPENDIX F Sample Purchase Order

STATEMENT OF WORK

PURCHASE ORDER NUMBER: *(fill in as needed)*

CONTRACTOR: Example: Chesapeake Biological Laboratory (CBL)

TITLE: Conduct water quality and quantitative analysis of water samples collected from waters adjacent to (list study site/s).

1.0 SCOPE: *(briefly describe the project)* Example: This project will provide the U.S. Army Environmental Center (USAEC) and the Directorate of Safety, Health, and the Environment (DSHE) with important water quality data and provide essential information needed in choosing favorable restoration sites for submersed aquatic vegetation (SAV) at APG.

Background.

Objective *(briefly describe the objective of the water quality analysis).* Example: The objective of this project is to conduct a long-term water quality monitoring

program adjacent to APG, in conjunction with USAEC's and DSHE's submersed aquatic vegetation program.

2.0 REQUIREMENTS: The contractor is an independent contractor and not an agent of the Federal government and shall provide the resources necessary to conduct the tasks herein.

3.0 TASKS: Example: CBL shall conduct quantitative analysis of water samples. Parameters to be measured are: total volatile suspended solids, chlorophyll *a*, dissolved inorganic nitrogen, and dissolved inorganic phosphorous. Approximately 28 water samples will be taken over a 7-month period (April 1–October 31, 2000).

Task 1. Example: Measure the amount of total suspended solids in each water sample in milligrams per liter (mg L^{-1}). Measure total volatile solids in each water sample in milligrams per liter (mg L^{-1}).

Task 2. Example: Measure chlorophyll *a* levels in each water sample in micrograms per liter ($\mu\text{g L}^{-1}$).

Task 3. Example: Measure dissolved inorganic phosphorous (ortho-phosphate) levels in each water sample in milligrams per liter (mg L^{-1}).

Task 4. Example: Measure dissolved inorganic nitrogen levels in each water sample in milligrams per liter (mg L^{-1}). Inorganic nitrogen is to include ammonium and nitrite + nitrate.

4.0 DELIVERABLES: Example: The contractor will provide deliverables in hard copy and 3.5-inch disk copy in Excel spread sheet format within 1 month of receiving water samples. Results are to be forwarded to the address below. Technique descriptions and detection limits are to be included.

Mailing addresses are as follows: *(Insert relevant information)*

5.0 GOVERNMENT-FURNISHED PROPERTY AND/OR ASSISTANCE:

Example: The Government will furnish information resources necessary for the performance of the tasks in this PO. Equipment, materials, and supplies to conduct the work shall be provided by the contractor.

6.0 PERIOD OF PERFORMANCE: Example: The period of performance for this PO is 12 months (April 1, 2000–March 31, 2001).

7.0 SERVICE COSTS: Example: Cost for each service is as follows:

- Total volatile solids and total suspended solids (TVS/TSS) = \$7.00 per sample
- Chlorophyll *a* (chl-*a*) = \$8.25 per sample
- Dissolved inorganic nitrogen (DIN) = \$9.80 per sample
- Dissolved inorganic phosphorus (DIP) = \$4.90 per sample.



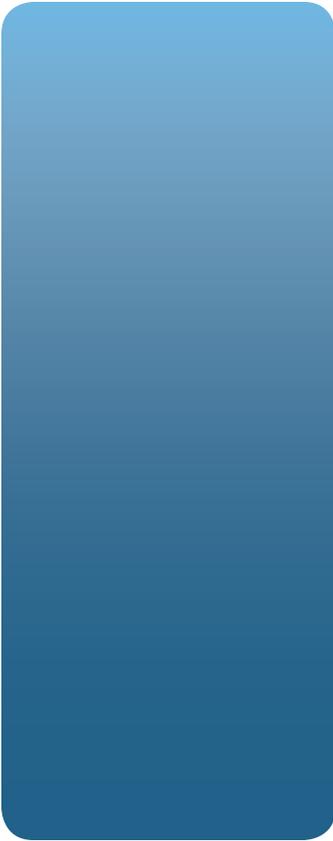
APPENDIX G Water Quality Sampling Protocol

All sites within the same river system should be sampled on the same day, preferably during the hours of 10 am and 2 pm, to ensure comparable light attenuation data (that is, adequate sun angle for determining light attenuation coefficients with a Secchi disk or a light meter). If light availability is the focus of sampling, measurements during flood tide are best; if water chemistry is the focus, an ebb tide is best. Make a note of the weather conditions on the data sheet. Sampling should be conducted on a clear day whenever possible. Always record any abnormal conditions, deviations in sampling procedures, or comments that may affect results. This information will help you interpret your results. Schedule alternative dates for sampling in the event that wave height is greater than 0.5 m or if adverse weather could prohibit sampling.

1. Gather and check all sampling equipment prior to departure (see checklist below).
 - Watercraft, paddles, anchor, life jackets
 - Device to measure water depth (for example, rod)

(checklist continues on next page)

- 
- ❑ Prelabeled Nalgene sampling bottles (1- or 2-L in volume).
 - ❑ Cooler and ice
 - ❑ Clipboard with the following:
 - Blank data sheets
 - Pencils, pens, and 2 black permanent markers
 - Map with GPS coordinates for each site
 - Laminated copy of the sampling protocol for reference
 - ❑ Kit with the following:
 - Secchi disk and depth-marked line
 - Depth-marked line with weight
 - GPS unit in waterproof case with spare batteries
 - Calibrated pH meter and buffers
 - ❑ Multifunction meter (for example, YSI 85) in waterproof case with spare batteries, membranes, and electrolyte solution
 - ❑ Calibrate and check all meters (that is, change membrane of the oxygen sensor if necessary and calibrate the oxygen and pH sensors)
 - ❑ Neoprene gloves (if needed).
2. Turn on the multifunction meter after launching the watercraft. Select percent dissolved oxygen (%DO) with the MODE button, and close the weatherproof container.

- 
3. Proceed to first sampling site. Maintain a consistent order when sampling multiple sites, sampling the downstream areas first and moving in an upstream direction. As each site is approached, minimize disturbance from paddling or outboard motor wash that would affect the water quality of your samples. Stop paddling (or cut the motor) and drop the anchor 10 to 15 ft from the site to avoid sediment resuspension. Anchor downstream of the site, and note the turbidity of the water before and after dropping the anchor to ensure that the sediments have not been disturbed. This observation is important in determining the order in which water quality parameters are sampled in step 5 below.
 4. Lower the meter probe into the water column to a depth of 6 to 8 in below the water surface. Tuck any residual cable under the meter to secure the cable and keep the probe at the desired depth. Let the meter acclimate to site conditions for at least 5 minutes.
 5. If sediments have been disturbed by your approach, wait until after the sediment plume has subsided. When the site has recovered, conduct your sampling in the order outlined below.
 - a. *Water sample collection*
 - 1) Rinse the pre-labeled (site, sample date, and sampler's initials) sample containers by unscrewing the lid, filling with water, replacing the lid,

and shaking vigorously for 3 to 5 seconds before discarding the water. Repeat this rinsing procedure 2 more times.

- 2) For a grab sample, vertically lower the sample container 6 in below the water surface. Fill container completely and then pour off enough water to leave approximately 1 in of air space at the top.
- 3) Cap tightly with the rinsed lid and place the container on ice in the cooler.

b. *Light attenuation (Secchi depth and/or Li-Cor) reading*

- 1) Slowly lower the Secchi disk over the sunny side of the boat until the Secchi disk is no longer visible (do not wear sunglasses). Mentally note the depth on the calibrated Secchi disk line.
- 2) Slowly raise the Secchi disk until it is visible, and then lower it again until it disappears. Record the depth at which the black and white portions of the Secchi disk are barely distinguishable.
- 3) If the Secchi disk is still visible on the bottom, take a reading at a deeper site or take a horizontal Secchi reading. A horizontal reading requires that one person hold the Secchi disk perpendicular to the bottom while another person (wearing a mask and snorkel) swims away while facing the disk until it is no longer visible. Record the distance at which the black and white portions of the Secchi disk can no longer be seen.

- 
- 4) If using a Li-Cor PAR sensor and meter, record the light level immediately below the water's surface, and at discrete intervals through the upper 2 m of the water column until the light level is <1% of the surface light level. Record the light level at each depth on the data sheet.

c. *Total depth measurement*

- 1) Measure total depth by slowly lowering a rod or weighted line into the water until it contacts the bottom. Note that it may be difficult to detect the bottom at sites with very fine sediments. Gently lower the device until you begin to feel some resistance.
- 2) Record total depth, tidal stage (high, low, flood, ebb) and time on the data sheet.

d. *Multifunction meter readings*

- 1) Meter readings should be fairly stable and acclimated to the water quality conditions before recording any values on the data sheet.
- 2) Record temperature ($^{\circ}\text{C}$), conductivity (μohms), salinity, dissolved oxygen (mg L^{-1} and as percentage), and pH by scrolling through the various modes (water quality parameters) on the meter. Note that to obtain an accurate measurement of dissolved oxygen, water movement across the probe is necessary. This is accomplished by slowly moving the cable so the probe gently moves back and forth.

- 3) Once you have recorded all measurements at approximately 6 to 8 in below the water surface, repeat the process at roughly 6 to 8 in above the bottom.

e. *pH meter*

- 1) Calibrate the pH probe and meter with field buffers.
- 2) Remove the pH meter probe from the last buffer and immerse electrode in the water. Make sure that the probe is at least 3 to 4 in below the water surface so that the membrane remains submerged.
- 3) Allow 1 to 2 minutes for the meter reading to stabilize and record pH reading and depth of the measurement. Cap the probe and turn off the meter until the next sampling station.

f. *SAV presence/absence*

- 1) Once all water quality parameters are recorded, take a garden rake and gently drag it along the sediment bottom at three different locations around the boat.
- 2) Record SAV species presence on the field datasheet. Percentage cover can be estimated visually within a quadrat of known size/area. For SAV species that cannot be positively identified, take a sample specimen; put it into a sealed plastic bag labeled with the site number, date, and observer's initials. Contact a plant biologist or SAV expert for assistance in identifying the species as soon as possible after returning from the field.

- 
6. Check each of the following before pulling up anchor and proceeding to the next site:
 - Water sample is capped tightly in a cooler
 - All monitoring equipment is secured to avoid damage or loss during transport
 - Leave the dissolved oxygen meter on but secured tightly in the waterproof carrying case
 - Check that all the fields on the data sheet have been completed for the site
 - Take a duplicate sample at one of the sampling sites.
 7. After all sites have been sampled, secure all the equipment and return to the laboratory to filter the samples.

APPENDIX H Field Water Monitoring Data Sheet

(data sheet is located on page H-2)

SAMPLE FIELD WATER MONITORING DATA SHEET													
Date:		Observers:				Air temperature:				°C			
Tide:		Wind speed:		m sec ⁻¹		Wind direction:		Weather:		Clear	Overcast	Variable	
Site	Time	Secchi depth (m)	Max. depth (m)	pH	Salinity (ppt)		Dissolved oxygen (mg L ⁻¹)		Conductivity (µs)		Water temperature (°C)		SAV coverage (% or Y/N)
					T	B	T	B	T	B	T	B	
Other comments/ species identified:													

T= top of water column; B = bottom of water column.



APPENDIX I

Water Sample Preparation and Filtering Protocols

Water samples should be placed on ice immediately after collection in the field. Samples should be processed and filtered in the laboratory within 6 hours collection. Perform the following procedures on unfiltered water samples to prepare them for subsequent laboratory analysis.

1. *Total Suspended Solids (TSS) and Total Volatile Solids (TVS)*
 - a. Rinse a sample bottle and all laboratory equipment (that is, graduated cylinders and filter apparatus) 3 times with the sample water to be filtered.
 - b. Rinse the part on the filter apparatus where the 47-millimeter (mm) filter sits (that is, the filter center) with distilled water.
 - c. Place a preweighed (0.00000 gram accuracy) 47-mm GF/F filter on the filter center. Secure filtering tower onto the filter apparatus, and filter a known volume of sample water through the system until color of the filter changes from white or off-white to tan or brown.
 - d. Rinse the inner sides of the filter tower and the filter itself with distilled water to remove salts as this can significantly increase the filter weight.

- e. Remove the filter and fold in half using 1 or 2 pairs of forceps. Avoid touching the material on filter with the forceps tips or fingers.
- f. Place the folded filter in aluminum foil labeled with the site name, date, volume filtered, filter identification number, and indicate that it is has been prepared for TSS/TVS analysis.
- g. Place all samples in a plastic bag, seal, and put on ice until samples can be frozen.
- h. Freeze plastic bags containing samples until delivery to an analytical laboratory.

2. *Chlorophyll-a (chl-a)*

- a. After obtaining samples for TSS/TVS, discard filtered water from the reservoir of the filtering apparatus. Do **NOT** rerinse filtering tower or filter center with distilled water.
- b. Place a 47-mm GF/F filter on the filter center. It is not necessary to weigh the filter.
- c. Filter a known volume of sample water through the filter apparatus until a noticeable coloration appears on the filter (generally 20% of the volume needed for TSS/TVS analysis). Do **NOT** rinse with distilled water.
- d. Fold and remove filter and place into aluminum foil labeled with site name, date, volume filtered, and indicate that it is has been prepared for chl-a analysis.

- 
- e. Place all samples in a plastic bag, seal, and place on ice.
 - f. Freeze plastic bags until delivery to an analytical laboratory.

3. *Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorus (DIP)*

- a. Rinse three 10-mL auto analyzer vials and caps 3 times with the filtered water from the chl-*a* procedure.
- b. Fill the vials to about 75% capacity with filtered water and place on ice until samples can be frozen. Leave enough space in the top of the vials for samples to expand when frozen.
- c. Place vials in freezer until delivery to an analytical laboratory.

4. *Total Nitrogen (TN) and Total Phosphorus (TP)*

- a. Rinse 1 test tube 3 times with sample water.
- b. Rinse a graduated cylinder or syringe with deionized water, and measure exactly 10 mL of sample water.
- c. Freeze test tubes until delivery to an analytical laboratory.

After performing the procedures described above, you should have the following samples prepared for each site:

- Two folded pieces of aluminum foil: one containing the TSS/TVS filter and the other containing the chl-*a* filter. Each piece of aluminum foil is labeled



with site, date, volume filtered, and either TSS/TVS or chl-*a*. Remember to include a filter identification number on the aluminum foil to be analyzed for TSS/TVS.

- Three auto analyzer vials for DIN/DIP labeled with site name on the top cap and the side of the vial. The sample date should be clearly labeled on the side of the vial.
- One test tube for TN/TP labeled with site name, date, and TN/TP on the side of the test.

Freeze foils, vials, and test tubes until delivery to an analytical laboratory.



APPENDIX J Resources for SAV Restoration, Funding, and Partnering

DO installations should take advantage of the wide array of partnership opportunities available to develop and implement ecosystem revitalization and restoration projects. Exhibit J-1 lists organizations with resources in the field of SAV restoration. Exhibit J-2 provides a list of funding sources and partnership opportunities. Exhibit J-3 contains links to additional information about SAV.

In most cases, federal entities are not directly eligible for many funding programs, such as grants, and should therefore partner with organizations that are eligible. For example, under the Sikes Act, the Army can partner with an environmental organization (for example, The Nature Conservancy) to obtain support and funding for conservation initiatives that meet the goals of both (USAEC 2002).

Exhibit J-1. Organizations with SAV Restoration Resources

Alliance for the Chesapeake Bay
<http://www.acb-online.org>

Chesapeake Bay Foundation
<http://www.cbf.org>

Chesapeake Bay National Estuarine Research
Reserve
<http://www.dnr.state.md.us/bay/cbnerr/>

Chesapeake Research Consortium Freshwater SAV
Partnership
[http://www.chesapeake.org/SAV/
partnershiphome.html](http://www.chesapeake.org/SAV/partnershiphome.html)

Harford Community College
[http://www.harford.edu/faculty/SKollar/home.
htm](http://www.harford.edu/faculty/SKollar/home.htm)

Harford County Parks and Recreation
http://www.co.ha.md.us/parks_rec

Maryland Department of Natural Resources
<http://www.dnr.state.md.us/bay/sav/index.html>

National Oceanic and Atmospheric Administration
<http://noaa.chesapeakebay.net/>

National Oceanic and Atmospheric Administration
Restoration Center
<http://www.nmfs.noaa.gov/habitat/restoration>

United States Geological Survey
[http://water.usgs.gov/nrp/proj.bib/sav/wethome.
htm](http://water.usgs.gov/nrp/proj.bib/sav/wethome.htm)

University of Maryland Center for Environmental
Science
<http://www.umces.edu/>; [http://www.hpl.umces.
edu/](http://www.hpl.umces.edu/)

Virginia Institute of Marine Sciences
<http://www.vims.edu/bio/sav>

Exhibit J–2. Funding Sources and Partnership Opportunities

Chesapeake Bay Trust

<http://www.chesapeakebaytrust.org/index.html>

Chesapeake Research Consortium Freshwater SAV
Partnership Funding Page

<http://www.chesapeake.org/SAV/funding/funding.html>

Cooperative Institute for Coastal and Estuarine
Environmental Technology

<http://ciceet.unh.edu>

The Foundation Center

<http://lnp.fdncenter.org/finder.html>

Maryland Sea Grant

<http://www.mdsg.umd.edu/Research/support.html>

National Oceanic and Atmospheric Administration
Grants

<http://noaa.chesapeakebay.net/grants.htm>

National Oceanic and Atmospheric Administration
Restoration Center

<http://www.nmfs.noaa.gov/habitat/restoration>

Penn State Institute of the Environment Listing of
Funding Opportunities and Grant Information

<http://www.environment.psu.edu/faculty/fundinglist.asp>

U.S. Fish and Wildlife Habitat Conservation
Planning Assistance Grants

<http://grants.fws.gov>

Exhibit J-3. Additional SAV Information

Chesapeake Bay Program

<http://www.chesapeakebay.net/baygras.htm>

Chester River Association

<http://www.chesterriverassociation.org>

Florida Department of Environmental Protection

<http://www.dep.state.fl.us/coastal/habitats/seagrass>

Jug Bay Wetlands Sanctuary

<http://www.jugbay.org/jugbay/research/sav.html>

Magothy River Association

<http://www.magothyriver.org/Plants.html>

SeagrassNet

<http://www.seagrassnet.org>

Weems Creek Conservancy

<http://www.weemscreek.org/Grasses.html>

SAV Float and Tank Construction

SAV FLOATS

Materials:

- ❑ 3 – 10-ft lengths of PVC pipe (4-in internal diameter (id))
- ❑ 3 – 10-ft lengths of PVC pipe (1-in id)
- ❑ 8 – 90° elbows for the 4-in id PVC sewer pipes
- ❑ 8 – 90° elbows for the 1-in id PVC pipes
- ❑ PVC cleaner
- ❑ PVC glue
- ❑ 2 – rolls of plastic fencing (height = 30 inches)
- ❑ 1 – large bag of 8-in cable ties
- ❑ 100 – 14-ft cable ties

Instructions:

1. The 4-in id sewer pipe comes with a female coupling that needs to be cut off and discarded.
2. Cut two 4-in id pipes in half. Cut another 4-in id pipe into 4 equal 2.5-ft sections. The 5-ft lengths of pipe will be the long sides (LS) of the float frame,

and the 2.5-ft lengths of pipe will be the short sides (SS). Follow the same procedures to cut the 3 1-in id PVC pipes.

3. Clean all ends of the pipe pieces with PVC cleaner. Glue the 90° elbows to both ends of each LS pipe. Carefully glue the LS and SS pipes together to form a rectangular shape. You should now have 2 rectangles made of 4-in PVC piping and 2 rectangles made of 1-in PVC piping. All rectangles should have dimensions of 5-ft long x 2.5-ft wide. Cut a 5.4-ft length of the plastic fence and secure it lengthwise to the 1-in PVC rectangle with cable ties. Make sure that the fencing overlaps the PVC ends. The 1-in PVC rectangle with plastic fencing will serve as the bottom of the float.
4. Create the sides of the float by cutting a 15-ft length of fencing and securing it with cable ties lengthwise along the inside of the 4-in PVC rectangle. Trim any excess fencing and stitch up the 30-in height junction with cable ties.
5. Place the float frame on the ground and carefully place the float bottom inside the frame. The bottom should fit snugly within the frame. Push the tank bottom down the length of the sides until there are at least 3 holes of fencing overlapping the bottom. Secure the bottom to the sidewalls by attaching cable ties through the overlap fencing.
6. Finish the float by trimming off the loose ends of the cable ties.

SAV TANKS

Materials:

- ❑ 36 – 4-ft x 4-ft boards
- ❑ 4 – 5/4-ft x 6-ft boards
- ❑ 4 – 2-ft x 8-ft boards
- ❑ 12 – deck screws
- ❑ 150 – lag bolts
- ❑ 10 – 50 lb bags of playground sand
- ❑ 8 – rebar stakes (length = 12–14 in)
- ❑ Liner material
- ❑ Power drill and bits
- ❑ Iron sledge hammer
- ❑ Shovels
- ❑ Garden rakes

Instructions:

1. On a level surface area with adequate room for the SAV tank, dig and level a hole that is 4 in to 6 in deep and slightly larger than the size of the tank to be built (for example, dig a 5-ft x 5-ft hole for a 4-ft x 4-ft SAV tank).

2. Lay 4 4-ft x 4-ft boards so they alternate at the ends. Screw the boards together with deck screws (see figure K-1b). Drill 8 holes (2 per board) approximately 12 in from the end of each 4-ft x 4-ft board and drive the rebar stakes into the holes, anchoring the 4-ft x 4-ft boards into the ground.
3. Lay the next 4 4-ft x 4-ft boards so that ends are overlapping the seams of the first set (see figure K-1a). Using a 1.5-in butterfly drill bit, drill two .5-in-deep holes, evenly spaced widthwise at each end of the 4-ft x 4-ft boards. This will allow the lag bolt head to recess deep enough so that the next layer of 4-ft x 4-ft boards are flush with the first layer of boards. After drilling the .5-in hole, use a drill bit that matches the size of the lag bolts being used and drill the rest of the way through



Figure K-1. Construction phase of an outdoor SAV tank. Notice (a) the overlapping corners, (b) how the bottom 4-ft x 4-ft board is set into the ground, (c) how the 5/4 x 6-ft deck is face mounted over the pond liner on the sides to hold it in place, and (d) how the top is 2-ft x 8-ft with 45° angles cut on the corners. PHOTO: J. BORTZ, CB-NERR



the 4-ft x 4-ft board and slightly into the 4-ft x 4-ft below it. Insert the lag bolt and tighten. For each layer of 4-ft x 4-ft boards, insert a total of 16 lag bolts (4 per board). Continue placing a layer of 4-ft x 4-ft boards on top of the next, following the procedures above until the desired height of the SAV tank is reached. For example, SAV tanks at Otter Point Creek Reserve were constructed of 8 layers of 4-ft x 4-ft boards. Remember to always predrill the large hole so that the head of the lag bolt is recessed and to overlap the seams of the 4-ft x 4-ft boards below.

4. After completing the layers of 4-ft x 4-ft boards, prepare the liner to fit into the tank. First, carefully check the inside of the tank for any large splinters, nails, or screws that could puncture the liner. Next, pour 6 50-lb bags of sand into the tank, and spread evenly to form a 1- to 1.5-inch layer on the bottom. Place the liner into the tank and flatten against the bottom and sides of the tank. Leave 10 in of liner overhanging all the sides when the tank is filled with water.
5. Start adding water to the tank. As the tank fills, 2 people at opposite corners of the tank will adjust the liner and fold excess liner material away from the tank corners so that the liner lays flat along the bottom and the sides. After the tank has filled to a depth of approximately 10 in, one person will pull the liner from the side walls toward the center, while the second person pours one 50-lb bag of playground sand into the corner. Lay the liner back in the corner and proceed to the next corner, repeating the procedure for the



remaining corners. Continue to flatten and tighten the liner to conform to the shape of the tank. Finally, fill the tank with water to the desired level.

6. Use the 5/4-ft x 6-ft boards to attach the liner to the outside of the tank with screws (figure K-1c). Face-mount the 5/4-ft x 6-ft boards to the tank walls with deck screws, making sure that the 5/4-ft x 6-ft boards are flush with the top of the side walls. Remove excess liner material after the 5/4-ft x 6-ft boards are secured.
7. Use the 2-ft x 8-ft boards to make the tank top ledge covers (figure K-1d). Rout the edges of the boards before installing to keep sawdust out of the tank. The boards should overhang the inside of the tank by no more than 1 in. Install the boards to the top of the tank with large deck screws or lag bolts, making sure that the screws/lag bolts are flush.

References

Note: References preceded by an asterisk (*) constitute an essential reading list for managers planning an SAV restoration project. Additionally, the Chesapeake Research Consortium Freshwater SAV Partnership maintains an on-line list of SAV reference materials (<http://www.chesapeake.org/SAV/partnershiphome.html>) that includes links to other on-line bibliographies.

Ailstock, M.S., W.J. Fleming, and T.J. Cooke. 1991. The characterization of axenic culture systems suitable for plant propagation and experimental studies of the submerged aquatic angiosperm *Potamogeton pectinatus* (sago pondweed). *Estuaries* 14:57–64.

Atlantic Flyway Council. 2003. Atlantic Flyway Mute Swan Management Plan. 30 pp.

*Batiuk, R.A., P. Bergstrom, M. Kemp, E. Koch, L. Murray, J.C. Stevenson, R. Bartleson, V. Carter, N.B. Rybicki, J.M. Landwehr, C. Gallegos, L. Karrh, M. Naylor, D. Wilcox, K.A. Moore, S. Ailstock, and M. Teichburg. 2000. Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis. CBP/TRS 245-00. Chesapeake Bay Program, Annapolis, MD.

- Batiuk, R.A., R.J. Orth, K.A. Moore, W. Dennison, J.C. Stevenson, L. Staver, V. Carter, N.B. Rybicki, R.E. Hickman, S. Kollar, S. Beiber, and P. Heasley. 1992. Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis. CBP/TRS 83/92. Chesapeake Bay Program, Annapolis, MD.
- Bergstrom, P.W., R.F. Murphy, M. Naylor, R.C. Davis, and J.T. Reel. 2005. Underwater Grasses in Chesapeake Bay & Mid-Atlantic Coastal Waters: Guide to Identifying Submerged Aquatic Vegetation. College Park, MD: Maryland Sea Grant College.
- Bird, K.T., J. Jewett-Smith, and S. Fonseca. 1994. Use of in vitro propagated *Ruppia maritima* for seagrass meadow restoration. *J. Coastal Res.* 10:732–737.
- Brandt, L.A. and E.W. Koch. 2003. Periphyton as a UV-B filter on seagrass leaves: A result of different transmittance in the UV-B and PAR ranges. *Aquat. Bot.* 76:317–327.
- Burrell, D.C. and J.R. Schubel. 1977. Seagrass ecosystem oceanography. In: C.P. McRoy and C. Helfferich (Eds.), *Seagrass Ecosystems: A Scientific Perspective*. pp. 196–232. Marcell Dekker, Inc., New York.
- Carlson, P.R., L.A. Yarbrow and T.R. Barber. 1994. Relationship of sediment sulfide to mortality of *Thalassia testudinum* in Florida Bay. *Bull. Mar. Sci.* 54:733–746.

- 
- Carter, V., J.E. Paschal, and N. Bartow. 1985. Distribution and abundance of submersed aquatic vegetation in the tidal Potomac River and Estuary, Maryland and Virginia, May 1978 to November 1981: U.S. Geological Survey Water Supply Paper 2234A. 46 pp.
- Chesapeake Bay Foundation Guide to Underwater Grasses. Chesapeake Bay Foundation, Annapolis, MD. (http://www.cbf.org/site/DocServer/Guide_to_Underwater_Grasses.pdf?docID=116).
- Conover, J.T. 1964. The ecology, seasonal periodicity, and distribution of benthic plants in some Texas lagoons. *Bot. Mar.* 7:4–41.
- Dan, A., A. Moriguchi, K. Mitsuhashi, and T. Terawaki. 1998. Relationship between *Zostera marina* and bottom sediments, wave action offshore in Naruto, Southern Japan. *Fisheries Eng.* 34:229–204.
- David, R. and J. Reel. 2001. Chesapeake Bay Submerged Aquatic Vegetation Identification Guide. Alliance for the Chesapeake Bay, Inc. (Note: Out of print).
- Davis, R.C. and F.T. Short. 1997. Restoring eelgrass, *Zostera marina* L., habitat using a new transplanting technique: The horizontal rhizome method. *Aquat. Bot.* 59:1–15.
- Davis, R.C., F.T. Short, and D.M. Burdick. 1998. Quantifying the effects of green crab damage to eelgrass transplants. *Restor. Ecol.* 6:297–302.

- Edgar, G.J. and C. Shaw. 1995. The production and trophic ecology of shallow-water fish assemblages in southern Australia: III. General relationships between sediments, seagrasses, invertebrates and fishes. *J. Exp. Mar. Biol. Ecol.* 194:107–131.
- Erftemeijer, P.L.A and E.W. Koch. 2001. Sediment geology methods for seagrass habitats. In: F.T. Short and R.G. Coles (Eds.). *Global Seagrass Research Methods*. pp 345–367. Elsevier Science, Amsterdam.
- Fishman, J.R. and R.J. Orth. 1995. Effects of predation on *Zostera marina* L. seed abundance. *J. Exp. Mar. Biol. Ecol.* 198:11–26.
- Fonseca, M.S., J.S. Fisher, J.C. Zieman, and G.W. Thayer. 1982. Influence of the seagrass *Zostera marina* on current flow. *Estuarine, Coastal and Shelf Sci.* 15:351–364.
- Fonseca, M.S. and W.J. Kenworthy. 1987. Effects of current on photosynthesis and distribution of seagrasses. *Aquat. Bot.* 27:59–78.
- Fonseca, M.S., W.J. Kenworthy, and F.X. Courtney. 1996. Development of planted seagrass beds in Tampa Bay, Florida, USA. I. Plant components. *Mar. Ecol. Prog. Ser.* 132:127–139.
- Fonseca, M.S., W.J. Kenworthy, F.X. Courtney, and M.O. Hall. 1994. Seagrass planting in the southeastern United States: Methods for accelerating habitat development. *Restor. Ecol.* 2:198–212.

- 
- *Fonseca, M.S., W.J. Kenworthy, and G.W. Thayer. 1998. Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. NOAA Coastal Ocean Program Decision Analysis Series No. 12. NOAA Coastal Ocean Office, Silver Spring, MD. 222 pp.
- Goodman, J.L., K.A. Moore, and W.C. Dennison. 1995. Photosynthetic responses of eelgrass (*Zostera marina* L.) to light and sediment sulfide in a shallow barrier island lagoon. *Aquat. Bot.* 50:37–47.
- Hannan, H.H. 1967. Macrophyte standing crop and metabolism in a constant temperature river. Ph.D. dissertation, Oklahoma State University, Stillwater, OK.
- Harwell, M.C. and R.J. Orth. 2001. Influence of a tube-dwelling polychaete on the dispersal of fragmented reproductive shoots of eelgrass. *Aquat. Bot.* 70:1–7.
- Harwell, M.C. and R.J. Orth. 2002. Long-distance dispersal potential in a marine macrophyte. *Ecology* 83:3319–3330.
- Holmer, M. and E.J. Bondgaard. 2001. Photosynthetic and growth response of eelgrass to low oxygen and high sulfide concentrations during hypoxic events. *Aquat. Bot.* 70:29–38.
- Hotchkiss, Neil. 1972. Common Marsh, Underwater, and Floating-Leaved Plants of the United States and Canada. Dover Publications, Inc., Mineola, NY. 223 pp.

- *Hurley, L.M. 1992. Field Guide to the Submerged Aquatic Vegetation of the Chesapeake Bay. U.S. Fish and Wildlife Service. Chesapeake Bay Estuary Program, Annapolis, MD. 52 pp. (*Note: Out of print*).
- Jessen, R. and R. Lound. 1962. An evaluation of survey techniques for submerged aquatic plants. Minnesota Department of Conservation, St. Paul, MN. Game Investigational Report No. 6. 10 pp.
- Joanen, T. and L.L. Glasgow. 1965. Factors influencing the establishment of widgeon grass stands in Louisiana. *Southeastern Assoc. Game Fish Commissioners Conf.* 19:78–92.
- Koch, E.W. 1994. Hydrodynamics, diffusion-boundary layers and photosynthesis of the seagrasses *Thalassia testudinum* and *Cymodocea nodosa*. *Mar. Biol.* 118:767–776.
- *Koch, E.W. 2001. Beyond light: Physical, geological and geochemical parameters as possible submersed aquatic vegetation habitat requirements. *Estuaries* 24:1–17.
- Koch, E.W. 2002. The impact of boat-generated waves on a seagrass habitat. *J. Coastal Res.* SI 37:66–74.
- Koch, E.W. and S. Beer. 1996. Tides, light and the distribution of *Zostera marina* in Long Island Sound, USA. *Aquat. Bot.* 53:97–107.

- 
- Koch, E.A. and M.J. Durako. 1991. In vitro studies of the submerged angiosperm *Ruppia maritima*: auxin and cytokinin effects on plant growth and development. *Mar. Biol.* 110:1–6.
- Koch, M.S. and J.M. Erskine. 2001. Sulfide as a phytotoxin to the tropical seagrass *Thalassia testudinum*: Interactions with light, salinity and temperature. *J. Exp. Mar. Biol. Ecol.* 266:81–95.
- Koch, E.W. and J. Verduin. 2001. Measurements of physical parameters in seagrass habitats. In: F.T. Short and R.G. Coles (Eds.). *Global Seagrass Research Methods*. pp. 325–344. Elsevier Science, Amsterdam.
- Kuhn, W.A. 1992. Interacting effects of light and sediment sulfide on eelgrass (*Zostera marina* L.) growth. M.S. Thesis, University of Maryland, College Park, MD. 90 pp.
- Madsen, T.V. and M. Sondergaard. 1983. The effects of current velocity on the photosynthesis of *Callitriche stagnalis*. *Aquat. Bot.* 15:187–194.
- Merrell, K.C. 1996. The effects of flow and mixing on *Vallisneria* and its associated community in experimental mesocosms. M.S. Thesis, University of Maryland, College Park, MD. 83 pp.
- Moore, K.A., D.J. Wilcox, B. Anderson, T.A. Parham, and M.D. Naylor. 2004. Historical analysis of SAV in the Potomac River and analysis of Bay-wide historic SAV to establish a new acreage goal. Final report to U.S. EPA,

Chesapeake Bay Program, Annapolis, MD. CB983627-01. (<http://www.vims.edu/bio/sav/savreports.html>).

Murphey, P.L. and M.S. Fonseca. 1995. Role of high and low energy seagrass beds as nursery areas for *Penaeus duorarum* in North Carolina. *Mar. Ecol. Prog. Ser.* 121:91–98.

Newell, R.I.E. and E.W. Koch. 2004. Modeling seagrass density and distribution in response to changes in turbidity stemming from bivalve filtration and seagrass sediment stabilization. *Estuaries* 27:793–806.

Noble, E.B. and R.J. Monroe. 1991. Classification of Pamlico Sound Nursery Areas: Recommendations for Critical Habitat Criteria. North Carolina Department of Environment, Health and Natural Resources, Division of Marine Fisheries Project Number 89-09. Morehead City, NC. 70 pp. plus appendices.

Norris, J.G., S. Wyllie-Echeverria, T. Mumford, A. Bailey, and T. Turner. 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. *Aquat. Bot.* 58:269–287.

Orth, R.J. 1975. Destruction of eelgrass, *Zostera marina*, by cownose ray, *Rhinoptera bonasus*, in the Chesapeake Bay. *Chesapeake Science* 16:205–208.

- 
- Orth, R.J., J.R. Fishman, D.J. Wilcox, and K.A. Moore. 2002. Identification and management of fishing gear impacts in a recovering seagrass system in the coastal bays of the Delmarva Peninsula, USA. *J. Coastal Res.* 37:111–129.
- Orth, R.J., M. Luckenbach, and K.A. Moore. 1994. Seed dispersal in a marine macrophyte: implications for colonization and restoration. *Ecology* 75:1297–1939.
- Orth, R.J. and K.A. Moore. 1983. An unprecedented decline in submerged aquatic vegetation. *Science* 222:51–53.
- Orth, R.J. and K.A. Moore. 1984. Distribution and abundance of submerged aquatic vegetation in the Chesapeake Bay: An historical perspective. *Estuaries* 7:531–540.
- Orth, R.J., J.F. Nowak, D.J. Wilcox, G.F. Anderson, D.J. Wilcox, J.R. Whiting, and L.S. Nagey. 1994. Distribution of submerged aquatic vegetation in the Chesapeake Bay and tributaries and Chincoteague Bay – 1995. Final Report U.S. EPA. 290 pp.
- Orth, R.J. and J. van Montfrans. 1990. Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus*: A latitudinal perspective. *Bull. Mar. Sci.* 46:126–144.
- *Orth, R.J., D.J. Wilcox, L.S. Nagey, A.L. Owens, J.R. Whiting, and A. Serio. 2003. 2002 Distribution of Submerged Aquatic Vegetation in the

Chesapeake Bay and Coastal Bays. VIMS Special Scientific Report Number 139. Final report to U.S. EPA, Chesapeake Bay Program, Annapolis, MD. CB983649-01. (<http://www.vims.edu/bio/sav/sav02>).

Phillips, R.C. 1974. Temperate grass flats. In: H.T. Odum, B.J. Copeland, and E.A. McMahan (Eds.). Coastal Ecological Systems of the United States. Vol. 2. The Conservation Foundation, Washington, DC. pp 244–314.

Pickerell, C. and S. Schott. 2003. (Abstract) Buoy-deployed seeding: A new approach to restoring seagrass using seed. Submerged Aquatic Vegetation Propagation Workshop, Baltimore, MD, September 3–4, 2003.

Posey, M.H., C. Wigand and J.C. Stevenson. 1993. Effects of an introduced aquatic plant, *Hydrilla verticillata*, on benthic communities in the Upper Chesapeake Bay. *Estuarine, Coastal and Shelf Sci.* 37:539–555.

Pulich, W.M. 1983. Growth response of *Halophila engelmannii* to sulfide, copper and organic nitrogen in marine sediments. *Plant Physiol.* 71:975–978.

Rawls, C.K. 1975. Mechanical control of eurasian watermilfoil in Maryland USA with and without 2, 4-D application. *Chesapeake Sci.* 16:266–281.

Scoffin, T.P. 1970. The trapping and binding of sub tidal carbonate sediments by marine vegetation in Bimini Lagoon, Bahamas. *J. Sedim. Petrol.* 40:249–273.



Sculthorpe, C.D. 1967. *The Biology of Aquatic Vascular Plants*. Edward Arnold Ltd., London. 610 pp.

Short, F.T., D.M. Burdick, S. Granger, and S.W. Nixon. 1996. Long-term decline in eelgrass, *Zostera marina* L., linked to increased housing development. In: J. Kuo, R.C. Phillips, D.I. Walker, and H. Kirkman (Eds.), *Seagrass Biology: Proceedings of an International Workshop, Rottnest Island, Western Australia, 25–29 January 1996*. pp 291–298. Nedlands, Western Australia: Sciences UWA.

Short, F.T., D. Burdick, J. Wolf, and G. Jones. 1993. Eelgrass in Estuarine Research Reserves along the East Coast, USA. Part I: Declines from pollution and disease; Part II: Management of eelgrass meadows. National Oceanic and Atmospheric Administration, Coastal Ocean Program through the Sea Grant College Program, Silver Spring, MD. 107 pp.

Short, F.T., R.C. Davis, B.S. Kopp, C.A. Short, and D.M. Burdick. 2002. Site-selection model for optimal transplantation of eelgrass *Zostera marina* in the northeastern US. *Mar. Ecol. Prog. Ser.* 227:253–267.

Smart, M. and G.O. Dick. 1999. Propagation and establishment of aquatic plants: A handbook for ecosystem restoration projects. U.S. Army Corps of Engineers. Technical Report A-99-4. Washington, DC. 38 pp. (<http://libweb.wes.army.mil/Archimages/69971.pdf>).

- Society for Ecological Restoration International Science & Policy Working Group. 2004. The SER International Primer on Ecological Restoration. (<http://www.ser.org/pdf/primer3.pdf>).
- Stankelis, R.M., M.D. Naylor, and W.R. Boynton. 2003. Submerged aquatic vegetation in the mesohaline region of the Patuxent Estuary: Past, present, and future status. *Estuaries* 26 SI 2A:186–195.
- STAC (Chesapeake Bay Program Scientific and Technical Advisory Committee). 2002. Chesapeake Futures: Choices for the 21st Century. D. Boesch and J. Greer (Eds.). STAC report 02-001, Edgewater, MD. 160 pp.
- Stephan, C.D., R.L. Peuser, and M.S. Fonseca. 2000. Evaluating Fishing Gear Impacts to Submerged Aquatic Vegetation and Determining Mitigation Strategies. ASMFC Habitat Management Series No. 5, Washington, DC. 38 pp.
- Stevenson, J.C. and N.M. Confer. 1978. Summary of available information on Chesapeake Bay submerged vegetation. U.S. Fish and Wildlife Service, Biological Services Program (FWS/OBS-78/66). 335 pp.
- Stevenson, J.C., M.S. Kearney, and E.W. Koch. 2002. Impacts of sea-level rise on tidal wetlands and shallowwater habitats: A case study from Chesapeake Bay. In: N.A. McGinn (Ed.), Fisheries in a Changing Environment. American Fisheries Society Symposium No. 32, Bethesda, MD. pp 23–36.

- 
- Stewart, R.M., D.G. McFarland, D.L. Ward, S.K. Martin and J.W. Barko. 1997. Flume study investigation of the direct impacts of navigation-generated waves on submersed aquatic macrophytes in the Upper Mississippi River. Environmental Report 1. U.S. Army Corps of Engineers, Vicksburg, MS. 52 pp. (http://www.mvr.usace.army.mil/pdw/nav_study/env_reports/env1.pdf).
- Thayer, G.W., M.S. Fonseca, and W.J. Kenworthy. 1997. Ecological value of seagrasses: a brief summary for the ASMFC Habitat Committee's SAV Subcommittee, pp. 5–10 in Stephan, C.D. and T.E. Bigford (Eds.), Atlantic Coastal Submerged Aquatic Vegetation: A Review of its Ecological Role, Anthropogenic Impacts, State Regulation and Value to Atlantic Coastal Fisheries. ASMFC Habitat Management Series No. 1. Washington, DC.
- USAEC (U.S. Army Environmental Center). 2002. Funding Resources Manual. Aberdeen Proving Ground, MD. 22 pp.
- USDOD (U.S. Department of Defense). 1998. Chesapeake Bay Report: Restoring and Protecting the Chesapeake Bay – A Department of Defense Initiative 1984–1997. Prepared By: Office of the Deputy Under Secretary of Defense (Environmental Security) and U.S. Army Environmental Center. 59 pp. (www.denix.osd.mil/denix/Public/News/Earthday98/Chesapeake/bay.html).

*USEPA (U.S. Environmental Protection Agency). 1993. Volunteer Estuary Monitoring: A Methods Manual. EPA 842-B-93-004. Office of Water, Washington, DC. (<http://www.epa.gov/owow/estuaries/monitor/>).

Werner, I. and G. Wise. 1982. Biomass production of submersed macrophytes in a selected stretch of the River Zschopau Southeast Germany with special regard to orthophosphate incorporation. *Int. Revue ges. Hydrobiol.* 67:45–62.

Westlake, D.F. 1967. Some effects of low-velocity currents on the metabolism of aquatic macrophytes. *J. Exp. Bot.* 18:187–205.

Woodhead, J.L. and K.T. Bird. 1998. Efficient rooting and acclimation of micropropagated *Ruppia maritima* Liosel. *J. Mar. Biotechnol.* 6:152–156.