Chesapeake Bay
Submerged Aquatic Vegetation Water Quality and Habitat-Based Requirements and Restoration Targets: A Second Technical Synthesis

August 2000

Printed by the United States Environmental Protection Agency
for the Chesapeake Bay Program

Chesapeake Bay Program
A Watershed Partnership

Printed on recycled paper

Executive Summary

The loss of submerged aquatic vegetation, or SAV, from shallow waters of Chesapeake Bay, which was first noted in the early 1960s, is a widespread, well-documented problem. Although other factors, such as climatic events and herbicide toxicity, may have contributed to the decline of SAV in the Bay, the primary causes are eutrophication and associated reductions in light availability. The loss of SAV beds are of particular concern because these plants create rich animal habitats that support the growth of diverse fish and invertebrate populations. Similar declines in SAV have been occurring worldwide with increasing frequency during the last several decades. Many of these declines have been attributed to excessive nutrient enrichment and decreases in light availability.

The health and survival of these plant communities in Chesapeake Bay and other coastal waters depend on suitable environmental conditions that define the quality of SAV habitat. These habitats have been characterized previously for Chesapeake Bay using simple models that relate SAV presence to medians of water quality variables. In *Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis*, published in 1992, SAV habitat requirements were defined in terms of five water quality variables: dissolved inorganic nitrogen, dissolved inorganic phosphorus, water-column light attenuation coefficient, chlorophyll *a* and total suspended solids. These SAV habitat requirements (Table 1, last five columns) have been used in conjunction with data from the Chesapeake Bay Monitoring Program as diagnostic tools to assess progress in restoring habitat quality for SAV growth in Chesapeake Bay. Attempts to use these habitat requirements to predict SAV presence or absence in Chesapeake Bay and elsewhere, however, have met with mixed success.

REVISING THE HABITAT REQUIREMENTS

Although the 1992 SAV habitat requirements have proved useful in factoring SAV restoration into nutrient reduction goal-setting for Chesapeake Bay, the original habitat requirements contain several limitations:

- It is unclear how many of the five requirements must be met to maintain existing SAV beds or establish new ones.
- The requirements ignore leaf surface light attenuation, which can be high enough to restrict SAV growth where there is a high epiphytic and sediment load on the leaf surface.
- There is no way to adjust the water-column light attenuation coefficient (K_d) requirement for variations in tidal range, or to adjust it for different SAV restoration depths.

For these reasons, we undertook this revision of the original habitat requirements.

The principal relationships between water quality conditions and light regimes for growth of SAV are illustrated in Figure 1, which represents an expansion of a similar conceptual diagram presented in the first SAV technical synthesis. Incident light, which is partially reflected at the water surface, is attenuated through the water column above SAV by particulate matter (chlorophyll *a* and total suspended solids), by dissolved organic matter and by water itself. In most estuarine environments, the water-column light attenuation coefficient is dominated by contributions from chlorophyll *a* and total suspended solids. This was the only component of light attenuation considered in the original habitat requirements.

Based on this conceptual model and an extensive review of the scientific literature, the original K_d habitat requirements were validated and reformulated as the “water-column light requirements” (Table 1). The attainment of the water-column light requirements at a particular site can be tested with the new “percent light through water” parameter (PLW), which is calculated from K_d and water-column depth and can be adjusted for both tidal range and varying restoration depths (Figure 2).

Light that reaches SAV leaves also is attenuated by the epiphytic material (i.e., algae, bacteria, detritus and

TABLE 1. Recommended habitat requirements for growth and survival of submerged aquatic vegetation (SAV) in Chesapeake Bay and its tidal tributaries.

		Primary Requirements[†]	Secondary Requirements[**] (Diagnostic Tools)				
Salinity Regime[#]	**SAV Growing Season[*]**	**Minimum Light Requirement (%)**	**Water Column Light Requirement (%)**	**Total Suspended Solids (mg/l)**	**Plankton Chlorophyll-*a* (μg/l)**	**Dissolved Inorganic Nitrogen (mg/l)**	**Dissolved Inorganic Phosphorus (mg/l)**
Tidal Fresh	April-October	>9	>13	<15	<15	—	<0.02
Oligohaline	April-October	>9	>13	<15	<15	—	<0.02
Mesohaline	April-October	>15	>22	<15	<15	<0.15	<0.01
Polyhaline	March-May Sept.-Nov.	>15	<22	<15	<15	<0.15	<0.02

[#] Regions of the estuary defined by salinity regime, where tidal fresh = <0.5 ppt, oligohaline = 0.5-5 ppt, mesohaline = >5-18 ppt and polyhaline = >18 ppt.

[*] 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 (see Chapter VII). For polyhaline areas, the data are combined for the two growing season periods shown.

[†] Minimum light requirement for SAV survival based on analysis of literature, evaluation of monitoring and research findings and application of models (see Chapters III, V and VII). Use the primary requirement, or minimum light requirement, whenever data are available to calculate percent light at the leaf (PLL) (which requires light attenuation coefficient [K_d] or Secchi depth, dissolved inorganic nitrogen, dissolved inorganic phosphorus and total suspended solids measurements).

[**] 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 non-attainment 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.

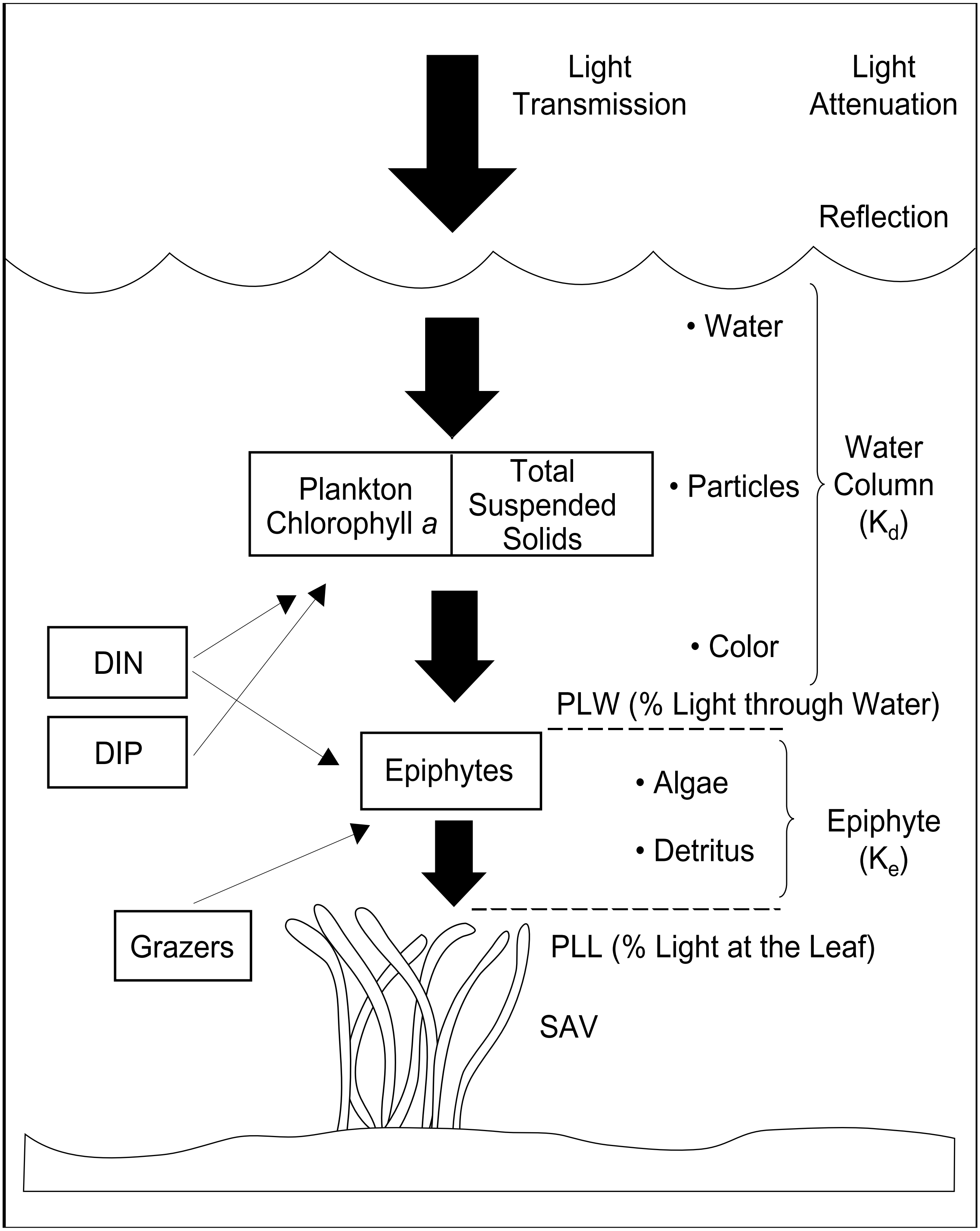

FIGURE 1. Conceptual Model of Light/Nutrient Effects on SAV Habitat. Availability of light for SAV is influenced by water column and at the leaf surface light attenuation processes. DIN = dissolved inorganic nitrogen and DIP = dissolved inorganic nitrogen.

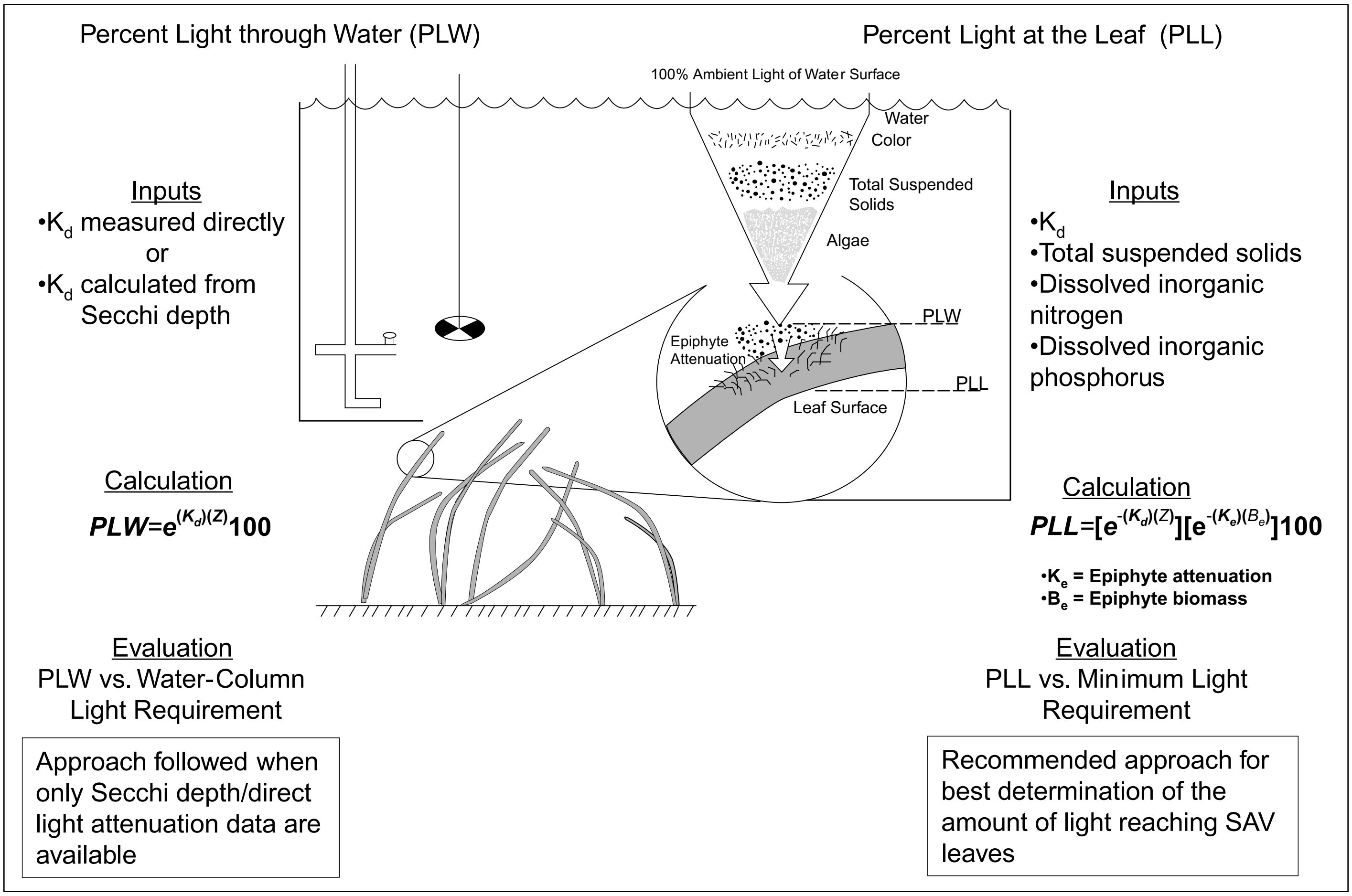

FIGURE 2. Calculation of PLW and PLL and Comparisons with their Respective Light Requirements. Illustration of the inputs, calculation and evaluation of the two percent light parameters: percent light through water and percent light at the leaf.

sediment) that accumulates on the leaves. This epiphytic light attenuation coefficient (called K_e) increases exponentially with epiphyte biomass, where the slope of this relationship depends on the composition of the epiphytic material. Dissolved inorganic nutrients in the water column stimulate growth of epiphytic algae (as well as phytoplankton), and suspended solids can settle onto SAV leaves to become part of the epiphytic matrix. Because epiphytic algae also require light to grow, water depth and K_d constrain epiphyte accumulation on SAV leaves, and light attenuation by epiphytic material depends on the mass of both algae and total suspended solids settling on the leaves. An algorithm was developed to compute the biomass of epiphytic algae and other materials attached to SAV leaves, and to estimate light attenuation associated with these materials. This algorithm uses monitoring data for K_d (or Secchi depth), total suspended solids, dissolved inorganic nitrogen and dissolved inorganic phosphorus to calculate the potential contribution of epiphytic materials to total light attenuation for SAV at a particular depth (Figure 2).

The SAV water-column light requirements were largely derived from studies of SAV light requirements, in which epiphyte accumulation on plant leaves was not controlled. Therefore, light measurements in those studies did not account for attenuation due to epiphytes. To determine minimum light requirements at the leaf surface itself, three lines of evidence were compared:

1. Applying the original SAV habitat requirements parameter values to the new algorithm for calculating PLL (Figure 2), for each of the four salinity regimes;
2. Evaluating the results of light requirement studies from areas with few or no epiphytes; and

3. Comparing median field measurements of the amount of light reaching plants' leaves (estimated through the PLL algorithm) along gradients of SAV growth observed within Chesapeake Bay and its tidal tributaries.

Minimum light requirements of 15 percent for mesohaline and polyhaline habitats and 9 percent for tidal fresh and oligohaline habitats resulted from the intersection of these three lines of evidence (Table 1). The attainment of the minimum light requirement at a particular site is tested by comparing it with the calculated PLL parameter (Figure 2).

VALIDATING THE REVISED REQUIREMENTS

The algorithm described above was applied to analyze SAV habitat suitability for some 50 sites in Chesapeake Bay and its tidal tributaries using data collected over 14 years (1985-1998) of environmental monitoring. For each monitoring site, values were calculated for PLW and PLL at 0.5-meter and 1-meter depths, adding half of the tidal range to those values. There was considerable variation in the relationship between PLL and PLW among sites throughout Chesapeake Bay, but clear patterns were evident (Figure 3). Light attenuation by epiphytic material appears to be generally important throughout Chesapeake Bay, contributing 20 to 60 percent additional attenuation (beyond that due to water-column light attenuation) in the tidal fresh and oligohaline regions, where nutrient and total suspended solids concentrations were highest, and contributing 10 to 50 percent in the less turbid mesohaline and polyhaline regions. These findings are consistent with the 30 percent additional light reduction expressed in the PLL value, which was calculated using the 1992 SAV habitat requirements, compared to the PLW parameter value, which was extracted from the same 1992 requirements.

We tested the robustness of this analysis by relating calculated values for PLL at 0.5-meter and 1-meter water depths to SAV presence (over a 10-year record) in areas adjacent to water quality monitoring stations. Five quantitative categories of SAV presence were defined based on SAV areas recorded over all years within the Chesapeake Bay and tidal tributaries' 70 segments. These categories were: always abundant (AA); always some (AS); sometimes none (SN); usually none (UN); and always none (AN). The observed patterns of percent light at the leaf surface versus SAV presence were then compared with the applicable minimum light requirement.

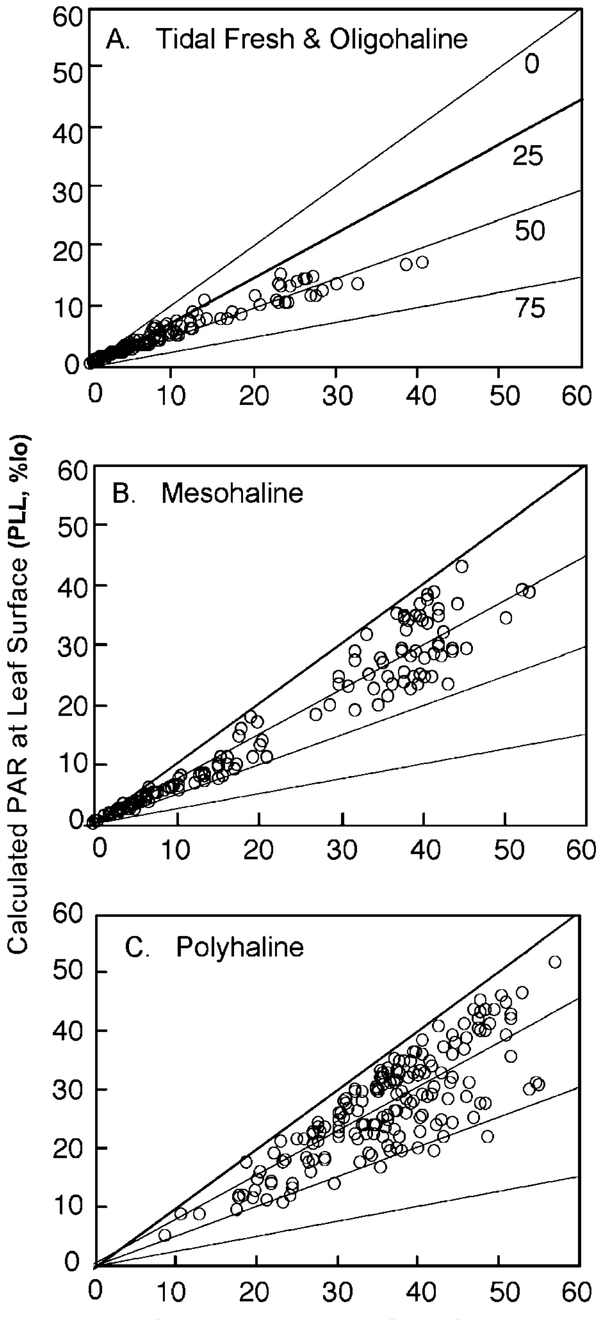

FIGURE 3. Percent Light at Leaf vs. Percent Light Through Water Column by Salinity Regime. Comparing values for percent surface light at SAV leaf surface (PLL) and percent surface light through water just above the SAV leaf (PLW) calculated for Z = 1 m from the model described in this report (Table V-1) for water quality monitoring stations in Virginia portion of Chesapeake Bay for 1985-1996 in three salinity regimes. Lines indicate position of points where epiphyte attenuation reduced ambient light levels at the leaf surface by 0, 25, 50 and 75 percent.

We assumed that water quality adequate to support SAV growth would be found in segments that fell in the AS and SN categories, since they always or usually had mapped SAV. Thus, we predicted that median PLL values for segments in those categories should be near the minimum light requirement. For the mesohaline and polyhaline regions of the Bay, we found excellent agreement (Figure 4) between the median PLL values calculated (at 1-meter depth plus half tidal range) for sites categorized as AS and SN (ranging from 13 to 18 percent) and the minimum light requirement value for these higher salinity areas (15 percent). The agreement was not as close, however, for the tidal fresh and oligohaline regions of the Bay. Median PLL values in these regions ranged from 5 to 8 percent for sites categorized as AS and SN, only exceeding the minimum light requirement value of 9 percent for segments in the AA category at the 0.5-meter restoration depth. For lower salinity segments in the AS or SN categories at the 1-meter restoration depth, the median PLL value was only 1 to 3 percent–far less than the expected 9 percent. SAV species that inhabit shallow waters (0.25 meters or less, even up to the intertidal zone) in the fresh and brackish reaches of the upper Bay and tidal tributaries are predominantly canopy-forming species that grow rapidly until they reach the water's surface. This appears to allow them to grow in low salinity sites where the estimated light level at the leaf at the restoration depth (e.g., 1 meter) is predicted to be inadequate to support SAV growth.

NEW ASSESSMENT AND DIAGNOSTIC CAPABILITIES

An important advancement in this report was the development of an SAV habitat assessment method that explicitly considers water depth requirements for SAV restoration. As SAV is generally excluded from intertidal areas because of physical stress (waves, dessication and freezing), the upper depth-limit for SAV distribution is usually determined by the low tide line. The maximum depth of SAV distribution, in turn, is limited by light penetration. A relatively small tidal range results in a larger SAV depth distribution (Figure 5A), whereas a large tidal range results in a smaller SAV depth distribution (Figure 5B). This is because the upper depth-limit for SAV distribution tends to be lower in areas with larger tidal range. Furthermore, the lower depth-limit tends to be reduced at sites

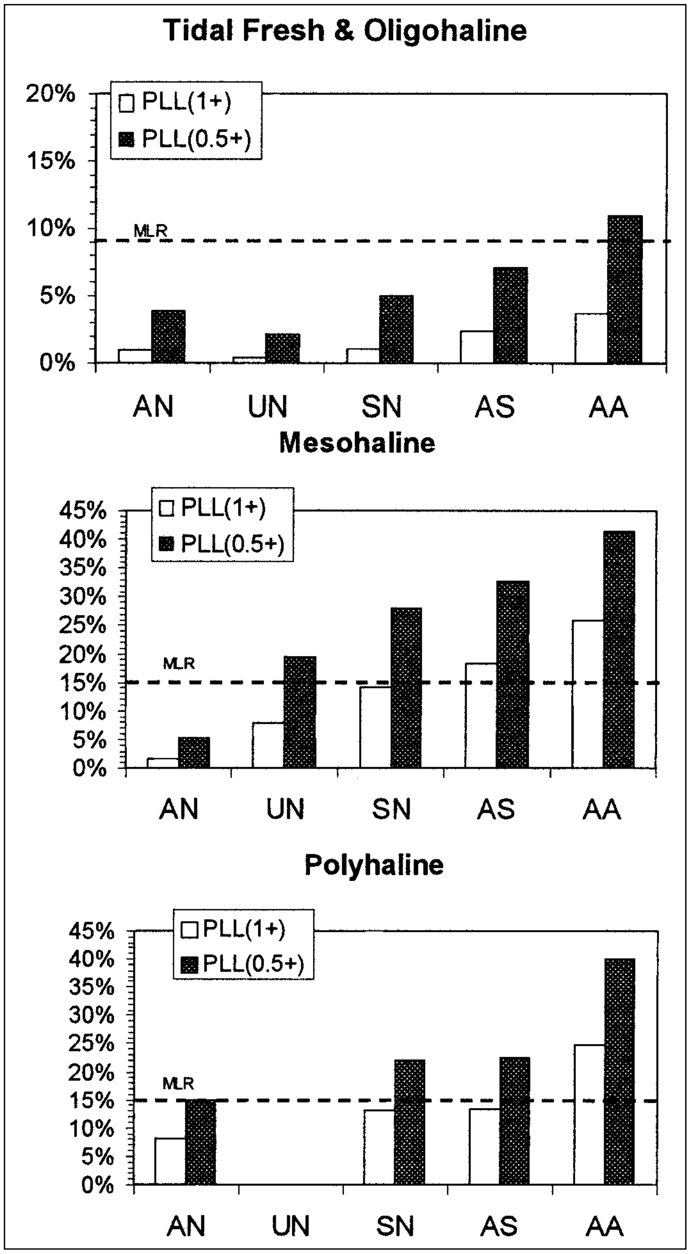

FIGURE 4. Comparison of PLL Values for Different Restoration Depths Across Salinity Regimes by SAV Abundance Category. SAV growing season median percent light at the leaf (PLL) calculated using 1985-1998 Chesapeake Bay Water Quality Monitoring Program data by SAV relative abundance category. AN = Always None, UN = Usually None, SN = Sometimes None, AS = Always Some, AA-Always Abundant. The applicable minimum light requirement (MLR) for each salinity regime is illustrated as a dashed line. The number with a plus symbol within parentheses after PLL indicates the restoration depth adjusted for tidal range.

with larger tidal range because of increased light attenuation through the longer average water column. Thus, there tends to be an inverse relationship between tidal range and the range of SAV depth distribution. When the PLW or PLL parameters are calculated, half the mean diurnal tidal range is added to the target SAV restoration depth value (Z) to reflect this relationship.

A management diagnostic tool was developed for quantifying the attenuation of light within the water column that is attributable to light absorption and scattering by dissolved and suspended substances in water and by water itself. Water-column attenuation of light measured by K_d was divided into contributions from four sources: water, dissolved organic matter, chlorophyll *a* and total suspended solids. The basic relationships were thus described by a series of simple equations, which were combined to produce the equation for the diagnostic tool. The resulting equation calculates linear combinations of chlorophyll *a* and total suspended concentrations that just meet the water-column light requirement for a particular depth (Figure 6) at any site or season in Chesapeake Bay and its tidal tributaries. This diagnostic tool can also be used to consider various management options for improving water quality conditions when the SAV water-column light requirements are not currently met.

This report defines SAV habitat requirements in terms of light availability to support plant photosynthesis, growth and survival. Other physical, geological and chemical factors may, however, preclude SAV from particular sites even when minimum light requirements are met. These effects on SAV are illustrated (Figure 7) as an overlay to the previous conceptualization (Figure 1) depicting interactions between water quality variables and SAV light requirements. Some of these effects operate directly on SAV, while others involve inhibiting SAV/light interactions. Waves and tides alter the light climate by changing the water-column height over which light is attenuated, and by resuspending bottom sediments, thereby increasing total suspended solids and associated light attenuation. Particle sinking and other sedimentological processes alter texture, grain-size distribution and organic content of bottom sediments, which can affect SAV growth by modifying availability of porewater nutrients and by producing reduced sulfur compounds that are phytotoxic. In addition, pesticides and other anthropogenic chemical contaminants tend to inhibit SAV growth. An extensive review of the literature revealed that certain SAV species and functional groups appear to have a limited range in their ability to tolerate selected physical, sedimentological and chemical variables (Table 2).

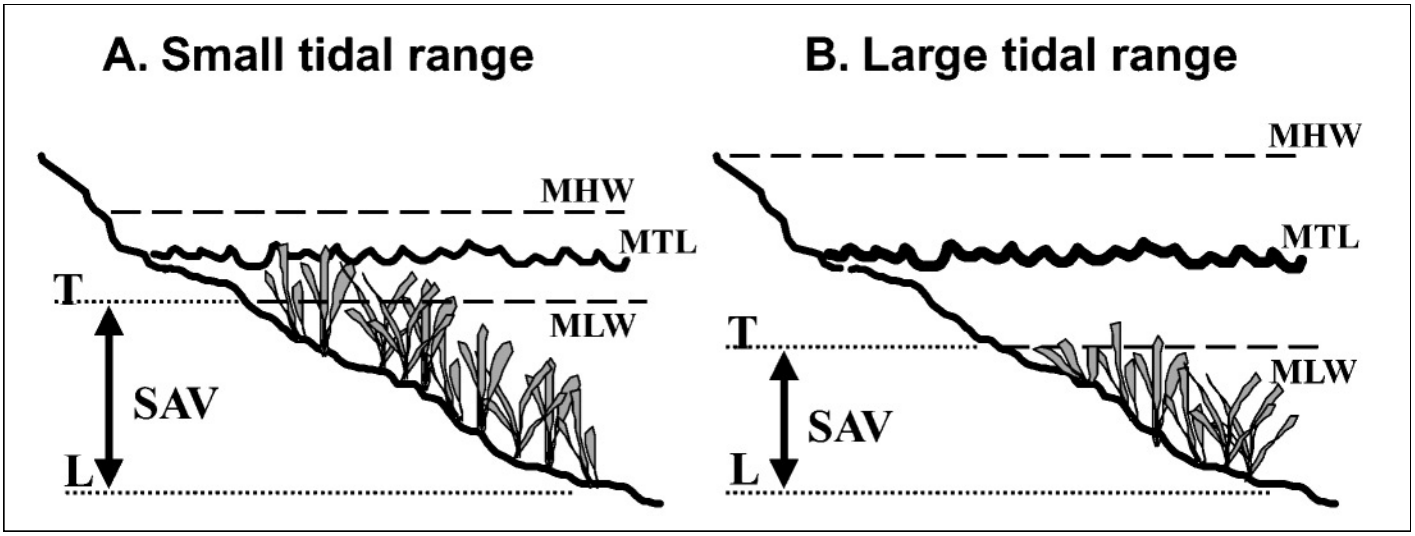

FIGURE 5. Tidal Range Influence on Vertical SAV Depth Distribution. The vertical range of distribution of SAV beds can be reduced with increased tidal range. The minimum depth of SAV distribution (Z_{min}) is limited by the low tide (T), while the maximum depth of SAV distribution (Z_{max}) is limited by light (L). The SAV fringe (arrow) decreases as tidal range increases. A small tidal range results in a large SAV depth distribution (A), whereas a large tidal range results in a small SAV depth distribution (B). Mean high water (MHW), mean tide level (MTL) and mean low water (MLW) are all illustrated.

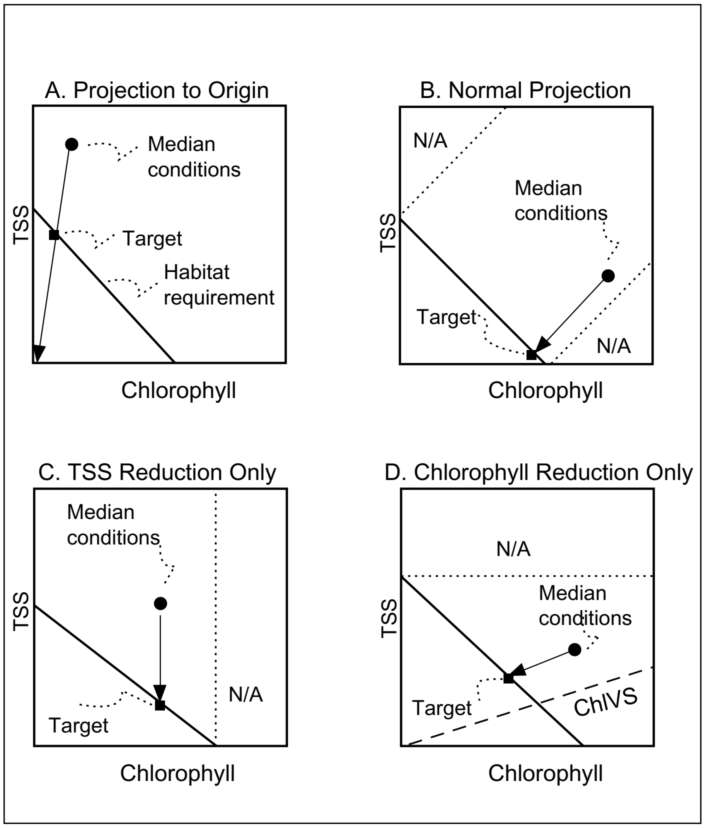

FIGURE 6. Illustration of Management Options for Determining Target Concentrations of Chlorophyll and Total Suspended Solids. Illustration of the use of the diagnostic tool to calculate target growing-season median concentrations of total suspended solids (TSS) and chlorophyll for restoration of SAV to a given depth. Target concentrations are calculated as the intersection of the minimum light habitat requirement, with a line describing the reduction of median chlorophyll and TSS concentrations calculated by one of four strategies: (A) projection to the origin (i.e. chlorophyll=0, TSS=0); (B) normal projection, i.e. perpendicular to the minimum light habitat requirement; (C) reduction in total suspended solids only; and (D) reduction in chlorophyll only. A strategy is not available (N/A) whenever the projection would result in a 'negative concentration'. In (D), reduction in chlorophyll also reduces TSS due to the dry weight of chlorophyll, and therefore moves the median parallel to the line (long dashes) for ChlVS, which describes the minimum contribution of chlorophyll to TSS.

The original tiered SAV distribution restoration targets for Chesapeake Bay, first published in the 1992 SAV technical synthesis, have been refined to reflect improvements in the quality of the underlying aerial survey database and depth contour delineations, based on an expanded baywide bathymetry database (Table 3). The previous targets did not include Tier II, which is potential habitat to 1-meter depth at mean lower low water, because this contour was not available in 1992. As of 1998, baywide SAV distributions covered 56 percent of the areas in the Tier I restoration goal and 16 and 10 percent of the tiers II and III restoration target areas, respectively.

One question raised in the original SAV technical synthesis, which continues to be relevant to this analysis, is the extent to which water quality monitoring data collected from midchannel stations in the Bay and its tidal tributaries represent conditions at nearshore sites where SAV potentially occurs. Several studies conducted by state agencies, academic researchers and citizen monitors since 1992 provided the basis for more comprehensive analysis of this question using data from the upper mainstem Chesapeake Bay and 12 tidal tributary systems. Results revealed that SAV habitat quality conditions are indistinguishable between nearshore and adjacent midchannel stations 90 percent of the time, when station pairs were separated by less than two kilometers.

SUMMARY

The present report provides an integrated approach for defining and testing the suitability of Chesapeake Bay shallow water habitats in terms of the minimum light requirements for SAV survival. It incorporates statistical relationships from monitoring data, field and experimental studies and numerical model computations to produce algorithms that use water quality data for any site to calculate potential light availability at the leaf surface for SAV at any restoration depth. The original technical synthesis defined SAV habitat requirements in terms of five water quality parameters based on field correlations between SAV presence and water quality conditions. In the present approach, these parameters are used to calculate potential light availability at SAV leaves for *any* Chesapeake Bay site. These calculated percent light at the leaf surface values are then compared to minimum light requirements to assess the suitability of a particular site as SAV habitat. Values for the minimum light requirements were derived from algorithm calculations of light at SAV leaves using the 1992 SAV habitat requirements,

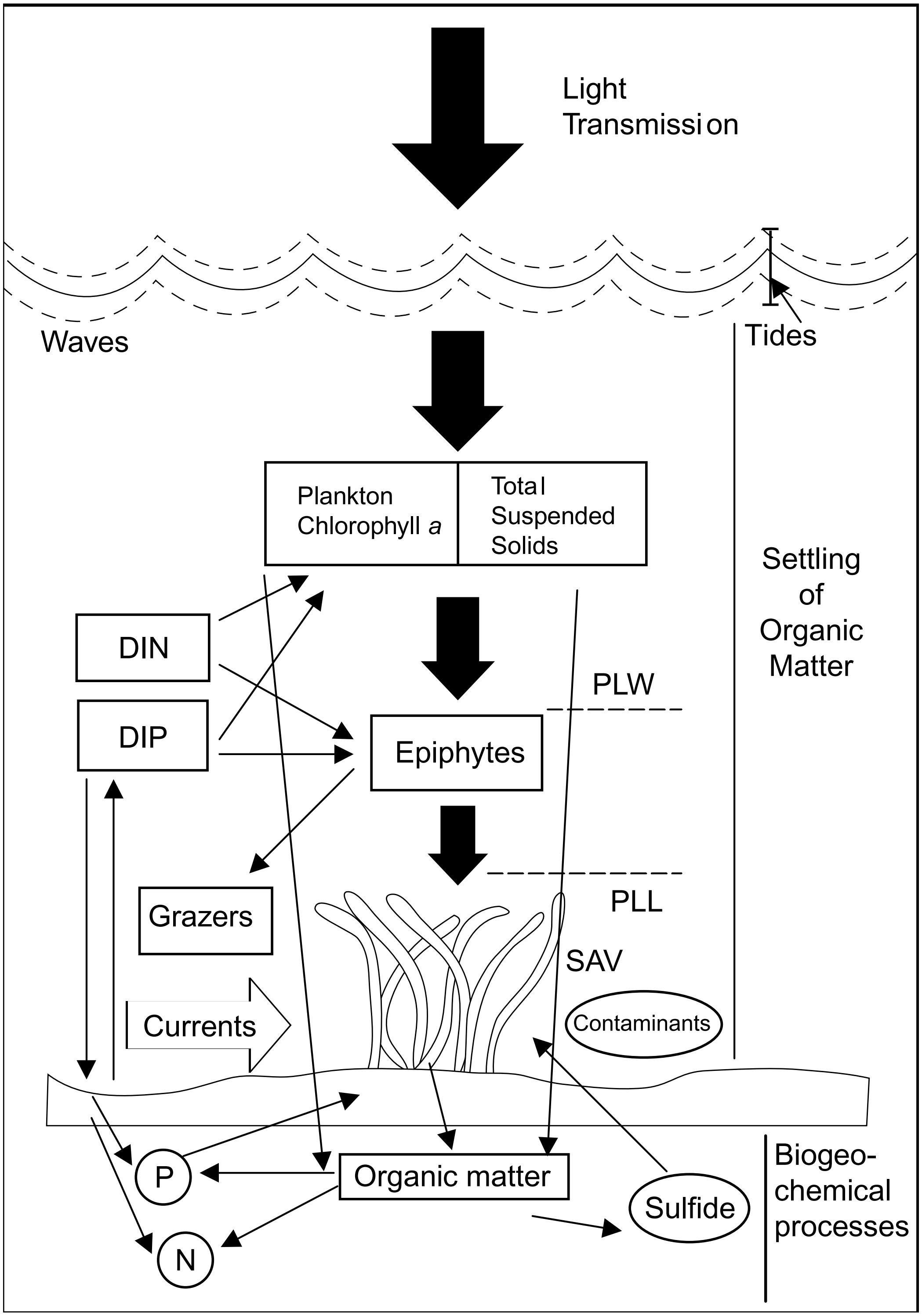

FIGURE 7. Interaction between Light-Based, Physical, Geological and Chemical SAV Habitat Requirements. Interaction between previously established SAV habitat requirements, such as light attenuation, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), chlorophyll a, total suspended solids (TSS) and other physical/chemical parameters discussed in this chapter (waves, currents, tides, sediment organic matter, biogeochemical processes). P = phosphorus; N = nitrogen; PLW = percent light through water; PLL = percent light at the leaf.

TABLE 2. Summary of physical and chemical factors defining habitat constraints for submersed aquatic plants.

Factor	Description	Constraint	Submersed Plants
Water Movement	Minimum velocities (cm s^{-1})	0.04-5	Freshwater plants
		3-16	Seagrasses
	Maximum velocities (cm s^{-1})	7-50	Freshwater plants
		50-180	Seagrasses
Wave Tolerance	Waves 0-1 m	Limited growth	Canopy formers (e.g., *Myriophyllum spicatum*, *Ruppia maritima* flowers)
	Waves >2 m	Tolerant growth	Meadow formers (e.g., *Zostera marina*, *Vallisneria americana*)
Sediments	Grain size (% fines, <64 µm)	2-62	Freshwater plants
		0.4-30	Seagrasses
	Organic matter (%)	0.4-12	Seagrasses and freshwater plants
Porewater Sulfide	(mM)	<1	Healthy plants
		>1	Reduced growth

TABLE 3. Chesapeake Bay SAV distribution targets and their relationships to the 1998 SAV aerial survey distribution data.

Restoration Target	Description	Area (acres)	1998 SAV Distribution as Percent of Restoration Target
Tier I–composite beds	Restoration of SAV to areas currently or previously inhabited by SAV as mapped through regional and baywide surveys from 1971 to 1990.	113,720	56%
Tier II–one meter	Restoration of SAV to all shallow-water areas delineated as existing or potential SAV habitat down to the one-meter depth, excluding areas identified as unlikely to support SAV based on historical observations, recent survey information and exposure regimes.	408,689	16%
Tier III–two meter	Restoration of SAV to all shallow water areas delineated as existing or potential SAV habitat down to the two-meter contour, excluding areas identified under the Tier II target as unlikely to support SAV as well as several additional areas between one and two meters.	618,773	10%

extensive review of the scientific literature and evaluation of monitoring and field research findings. These calculations account for regionally varying tidal ranges, and they partition total light attenuation into water-column and epiphyte contributions; water-column attenuation is further partitioned into effects of chlorophyll *a*, total suspended solids and dissolved organic matter. This approach is used to predict the presence of suitable water quality conditions for SAV at all monitoring stations around the Bay. These predictions compared well with results of SAV distribution surveys in areas adjacent to water quality monitoring stations in the mesohaline and polyhaline regions, which contain 75 to 80 percent of all recent mapped SAV areas and potential SAV habitat in the Bay and its tidal tributaries.

The approach for assessing SAV habitat conditions described in this report represents a major advance over that presented in 1992. At the same time, areas requiring further research, assessment and understanding have been brought into sharper focus. The key relationships within the algorithm developed for calculating epiphytic contributions to light attenuation can be strengthened and updated with further field and experimental studies. Particular attention needs to be paid to the relationships between epiphyte biomass and nutrient concentrations and between total suspended solids and the total mass of epiphytic material, and to a better understanding of the relationships in lower salinity areas. Detailed field and laboratory studies are needed to develop quantitative, species-specific estimates of minimum light requirements both for the survival of existing SAV beds and for reestablishing SAV into unvegetated sites. Although this report also provides an initial consideration of physical, geological and chemical requirements for SAV habitat, more work is needed to develop integrated quantitative measures of SAV habitat suitability in terms of physical, geological and chemical factors.

Principal Authors

Richard A. Batiuk
U.S. Environmental Protection Agency
Chesapeake Bay Program Office
Annapolis, Maryland

Peter Bergstrom
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
Annapolis, Maryland

Michael Kemp, Evamaria Koch, Laura Murray,
J. Court Stevenson, and Rick Bartleson
University of Maryland Center
for Environmental Studies
Horn Point Laboratory
Cambridge, Maryland

Virginia Carter, Nancy B. Rybicki,
and Jurate M. Landwehr
U.S. Geological Survey
Water Resources Division
Reston, Virginia

Charles Gallegos
Smithsonian Institution
Smithsonian Environmental Research Center
Edgewater, Maryland

Lee Karrh and Michael Naylor
Maryland Department of Natural Resources
Resource Assessment Service, Tidewater Ecosystem Assessment
Annapolis, Maryland

David Wilcox and Kenneth A. Moore
College of William and Mary
Virginia Institute of Marine Science
Gloucester Point, Virginia

Steve Ailstock
Anne Arundel Community College
Arnold, Maryland

Mirta Teichberg
Chesapeake Research Consortium, Inc.
Edgewater, Maryland

Acknowledgments

The development of this second technical synthesis was made possible by the efforts of authors of the initial technical synthesis and numerous investigators, field and laboratory technicians, program managers and many other people over the past three decades.

Technical comments and suggestions provided by the following independent peer reviewers are fully acknowledged: John Barko, U.S. Army Corps of Engineers Waterways Experimental Station; Ryan Davis, Alliance for the Chesapeake Bay; Kellie Dixon, Mote Marine Laboratory; Ken Dunton; University of Texas Marine Science Institute; Mike Durako, University of North Carolina Center for Marine Science Research; Mark Fonseca, NOAA National Marine Fisheries Service Science Center-Beaufort Laboratory; Jim Fourqurean, Florida International University; Brian Glazer, University of Delaware College of Marine Studies; Holly Greening, Tampa Bay Estuary Program; Dick Hammerschlag, U.S. Geological Survey; Will Hunley, Hampton Roads Sanitation District; W. Judson Kenworthy, NOAA National Marine Fisheries Service Science Center-Beaufort Laboratory; Hilary Neckles, U.S. Geological Survey; Harriette Phelps, University of District of Columbia; Kent Price, University of Delaware College of Marine Studies; Fred Short, University of New Hampshire Jackson Estuarine Laboratory; Michael Smart, Lewisville Aquatic Ecosystem Research Facility; John Titus, Binghamton University; Dave Tomasko, Southwest Florida Water Management District; Robert Virnstein, St. Johns Water Management District; Lexia Valdes, University of Delaware College of Marine Studies; and Richard Zimmerman, Hopkins Marine Station.

The technical editing skills of Robin Herbst, University of Maryland Eastern Shore, drew together the work of 17 authors into a single, integrated technical synthesis.

The Chesapeake Bay Program's Living Resources Subcommittee has contributed directly to this second technical synthesis through their funding support of the research needs identified through the 1992 synthesis and continued funding of the annual baywide SAV aerial survey program. This management commitment to funding research supported a second synthesis cycle: synthesis of available data and information; identification of unmet management information needs; funding of required research; continued commitment to long-term monitoring followed by another round of synthesis and management application of new findings.

Funding for the compilation of this second technical synthesis was from the U.S. Environmental Protection Agency through a cooperative agreement with the Chesapeake Research Consortium. Funding for the research and monitoring results reported here came from a wide variety of dedicated agencies whose contributions to Chesapeake Bay SAV research, distribution surveys, and long term water quality monitoring programs are hereby acknowledged.

Contents