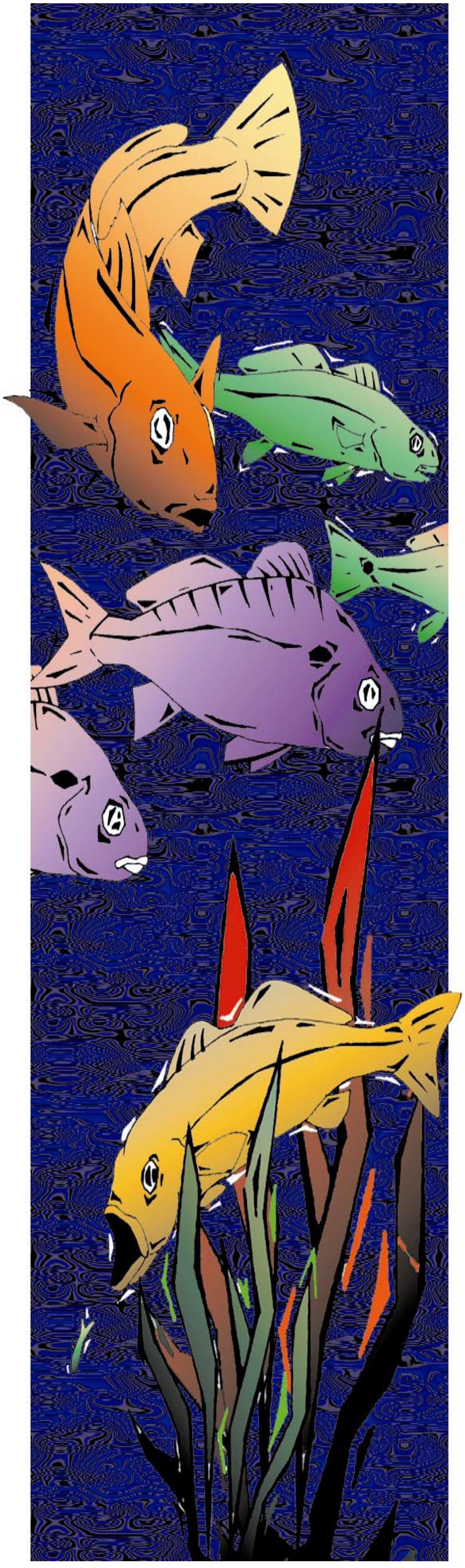


Atlantic States Marine Fisheries Commission

Evaluating Fishing Gear Impacts to Submerged Aquatic Vegetation

and

Determining Mitigation Strategies

ASMFC Habitat Management Series # 5

July 2000

ASMFC Habitat Management Series # 5

Evaluating Fishing Gear Impacts to Submerged Aquatic Vegetation

and

Determining Mitigation Strategies

by

C. Dianne Stephan[1]
Robin L. Peuser
Atlantic States Marine Fisheries Commission

and

Mark S. Fonseca[2], Ph.D.
National Ocean Service
National Oceanic and Atmospheric Administration

Atlantic States Marine Fisheries Commission
1444 Eye Street, NW, Sixth Floor
Washington, DC 20005

Authors addresses: [1]National Marine Fisheries Service, 1 Blackburn Drive, Gloucester, MA 01930; [2]National Ocean Service, Beaufort Laboratory, 101 Pivers Island Road, Beaufort, NC 28516

ACKNOWLEDGEMENTS

The Work Group that generated the approach and reviewed the information in this report consisted of: Seth Barker (Maine Division of Marine Resources), Peter Bergstrom (US Fish and Wildlife Service Annapolis, MD), Laura Ernst (Rhode Island Coastal Resources Management Council), Mark Fonseca (National Ocean Service Beaufort Laboratory), Jon Kurland (National Marine Fisheries Service Northeast Region), Wilson Laney (US Fish and Wildlife Service, South Atlantic Fisheries Coordination Office), Robert Orth (Virginia Institute of Marine Science), Jim Uphoff (Maryland Department of Natural Resources), and ASMFC Staff Robin Peuser and Dianne Stephan.

Special thanks to Virginia Carter (US Geological Survey), Peter Bergstrom (US Fish and Wildlife Service), Mike Naylor (Maryland Department of Natural Resources) and Phil Colarusso (Environmental Protection Agency) for additional reviews and technical support. Thanks to Jeff Rester (Gulf States Marine Fisheries Commission) for a complete literature review.

This report was reviewed and approved by the ASMFC Habitat Committee (Bill Goldsborough, Chesapeake Bay Foundation, Chair; Lance Stewart, University of Connecticut Vice-chair; Senator Louis Bassano, NJ Legislature; Ernie Beckwith, CT Marine Fisheries; Tom Bigford, National Marine Fisheries Service; Paul Caruso, MA Division of Marine Fisheries; Rob Dunlap, SC Department of Natural Resources; Tom Fote (proxy for Sen. Bassano), Jersey Coast Anglers Association; Bruce Freeman, NJ Department of Environmental Protection; Dan Kuzmeskus and Wilson Laney, US Fish and Wildlife Service; Sandra Lary, ME Division of Marine Resources; Lenny Nero, FL Department of Environmental Protection; Art Newell, NY Department of Environmental Conservation; Chris Powell, RI Division of Fish and Wildlife; Roger Pugliese, South Atlantic Fishery Management Council; Melvin Shepard, NC Coastal Federation; Mike Street, NC Division of Marine Fisheries) and the ASMFC Management and Science Committee. The Interstate Fisheries Management Program (ISFMP) Policy Board was instrumental in pursuing resolution of the issue of gear impacts to submerged aquatic vegetation. The support of Commission staff Jeff Brust, Dieter Busch, Jack Dunnigan, Lisa Kline, Carrie Selberg, Linda Schwab, Leuvet Stevens and Geoff White is appreciated.

Document reviewers contributed greatly to the finished product, and included the Work Group members, Phil Colarusso and Eric Nelson (Environmental Protection Agency), Mike Naylor and Harley Speir (MD Department of Natural Resources), Jack Terrill, Eric Hutchins and Mike Ludwig (National Marine Fisheries Service), Chris Powell (RI Division of Fish and Wildlife), Arnie Howe (MA Division of Marine Fisheries), Curtis Kruer, and Stu Kennedy (FL Department of Natural Resources). Additional information was provided by Charlie Lesser (DE Department of Natural Resources and Environmental Control), Bruce Halgren (NJ Department of Environmental Protection), John Nelson and Douglas Grout (NH Fish and Game Department), Chris Bonzek (VA Institute of Marine Sciences), Linda Mercer (ME Department of Marine Resources), Byron Young (NY Department of Environmental Conservation); Rob O'Reilly (VA Marine Resources Commission) and Carrie Selberg (ASMFC).

The Northeast Region of the National Marine Fisheries Service, Habitat Conservation Division generously contributed to preparation of this manuscript. Thanks to Kathie Ciarametaro and Mary Fowler for administrative support.

This report was funded in part by grant # NA07FGO024 and # NA97FGO0034 from the National Oceanic and Atmospheric Administration (NOAA). Printing was funded by NOAA Fisheries Office of Habitat Conservation's Essential Fish Habitat Program. The views expressed herein are those of the ASMFC, and do not necessarily reflect the views of NOAA or any of its agencies.

EXECUTIVE SUMMARY

The Atlantic States Marine Fisheries Commission (ASMFC or Commission) is an organization of the fifteen Atlantic coast states that works to cooperatively manage the states' common migratory marine fisheries resources. The Commission's interest in submerged aquatic vegetation (SAV) stems from the important role this habitat plays in critical life history stages of ASMFC managed species. Of the 24 species managed by ASMFC, over half of them derive benefits from association with SAV (Laney 1997). To enhance protection of SAV, the Commission adopted an SAV policy in 1997 with the goal of preserving SAV, and ultimately achieving a net gain in SAV distribution and abundance.

Although most of the agencies represented on the Commission do not have authority or have limited authority to regulate habitat protection, most are able to regulate fisheries in order to protect habitat. The policy directs the Commission to develop technical guidelines and standards to objectively determine fishing gear impacts to SAV, and develop standard mitigation strategies. The Commission appointed a Work Group to draft these guidelines and strategies. Commission staff, with assistance from the Work Group and additional technical experts, prepared this report, which was approved by the Commission's Management and Science Committee and Habitat Committee on November 2, 1999, and adopted by the Interstate Fisheries Management Program Policy Board on February 9, 2000.

As defined in the Commission's SAV policy (ASMFC 1997), SAV are "rooted, vascular, flowering plants (angiosperms) that, except for some flowering structures, live and grow below the water surface." This includes eight species of marine seagrasses, as well as 20-30 species of freshwater macrophytes (brackish species) found in tidal freshwater and low salinity areas. SAV are found in all Atlantic coast states, with the exception of Georgia and South Carolina, where tidal amplitude and turbidity combine to inhibit their growth. Based on this definition, algae are not considered SAV. This report is limited in scope to tidal, estuarine, and marine ecosystems.

The initial step of determining exactly what constitutes SAV in terms of spatial and temporal distribution -- in other words, determining the boundaries of SAV-habitat -- is critical. The Commission's SAV policy supports the use of the national mapping protocol (Dobson et al. 1995). Patchy areas have been found to provide similar ecological functions as continuous cover SAV-habitat. For marine SAV, evidence suggests that a patch must be maintained by a surrounding unvegetated area of at least twice the patch size. Defining SAV-habitat boundaries in patchy cover presents a difficulty that is addressed in the report. The status of SAV mapping is reviewed for each state. Mapping is incomplete for NH, RI, NY, and NC. Mapping was completed prior to 1990 in NJ.

Certain specific characteristics of SAV are reviewed in the document, since these characteristics may influence SAV susceptibility to damage or loss from fishing gear impacts. The importance of these features vary among species and geographic location. The characteristics of concern include light requirements, asexual reproductive structures (also called growing tips or meristems), reproductive structures (flowers and seeds), and ability to recover from disturbance or injury. An additional factor that can affect SAV susceptibility to physical damage is the substrate type in which the SAV is found.

Injuries that could result from fishing gear are categorized as physical disturbance to plants or increases in turbidity. Physical disturbances are of great concern, and are classified as leaf shearing, seed or flower shearing, uprooting, below-ground impacts, or burial. Below-ground impacts are identified as the disturbance of greatest concern since serious damage to roots, rhizomes and meristems can result. Cumulative impacts are also identified as a concern.

Sources of impact are identified as attributable directly to fishing gears, or as the result of fishery related shoreside activities or aquaculture. Fishing gear used in state estuarine waters and SAV are identified and described, including their potential impacts to SAV. Gears or fishing practices that could cause below-ground impacts were identified as clam kicking, hydraulic clam dredging, bay scallop/oyster/mussel/etc. dredges (toothed), and hand or vessel operated rakes or tongs. Impacts of trawls, toothless bay scallop dredges, and toothless crab scrapes, must be evaluated on a case-by-case basis, considering factors such as injury type, magnitude, and temporal extent, and the susceptibility of the injured SAV species.

Impacts that result in loss of SAV-habitat are considered to be "impacts of significant concern" based on the goals of the Commission's SAV policy. Below-ground impacts clearly cross the threshold of impact of significant concern. In addition, many above-ground impacts will result in death for the marine species *Halophila.* Determination of impact significance for above-ground impacts to other species is extremely difficult to impossible with the data currently available. Factors to consider are outlined in the report.

Mitigation strategies are identified as avoidance, minimization, restoration and creation. Only the first two strategies are considered viable because of the difficulty in developing effective restoration efforts for SAV-habitat restoration and creation. Year round closures to all gear and gear prohibitions are identified as options for avoiding impacts to SAV. Options for impact minimization include partial area closures and gear format restrictions or modifications. The report documents current gear regulations for each state that may result in reduction of impacts to SAV-habitat.

The final report section describes guidelines for applying the mitigation strategies identified, based on the postulates and conclusions that were derived in earlier sections. A decision tree graphically depicts guidance for applying mitigation strategies, as described below.

Impacts of significant concern have been shown to result unequivocally from below-ground impacts to most SAV species, and above-ground disturbance for *Halophila* spp. Fishing gear that result in below-ground disturbances are identified in Table 5. This type of impact should be avoided at most costs, and the "Avoidance" mitigation strategy should be applied. Disturbance to sexual reproduction is the impact of next greatest concern. Impacts that interfere with flowering or seed setting may affect the amount of SAV present in the upcoming year. In most cases, partial area closures should be used to offset any seasonal impacts of concern. More risk-averse actions, such as full area closures, may also be used.

The impacts which do not fit into these three categories of impacts [(1) below-ground disturbance; (2) impact to *Halophila*; (3) sexual reproduction disturbance] must be evaluated for degree of impact. As stated earlier in the report, this degree of impact determination is subjective since so little scientific research has occurred in this discipline. Factors which should be considered in this evaluation are described in the section of the report entitled "*Determining Impacts of Significant Concern.*" If the degree of impact to SAV is considered to be high, then minimization strategies should be employed. If the degree of impact is low, then other environmental stresses should be taken into account when evaluating the need for mitigation. If there is little additional stress such as poor water quality, then no action is required.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

TABLES

FIGURES

PREFACE

The Atlantic States Marine Fisheries Commission (ASMFC or Commission) is an organization of the fifteen Atlantic coast states that works to cooperatively manage the states' common migratory marine fisheries resources. The Commission was created in the early 1940s and formalized by an interstate compact approved by Congress. The functioning of the Commission has evolved with the advent of various federal statutes, but its purpose has remained true to its initial charge of protecting and conserving migratory coastal fisheries resources.

The Commission's involvement in habitat protection was initiated in 1980, and has continued to expand in order to support the vital connection between managed fish stocks and their habitat. Coastwide habitat loss and degradation resulting from the pressures of coastal population growth absolutely require that resource managers seriously consider the future of the nearshore environment. Loss of fish habitat is generally recognized as the greatest threat to the sustainability of nearshore fisheries resources. The Commission's approach to habitat protection includes maximizing the integration of fisheries management with habitat management through venues such as fisheries management planning, policy development, and technical information transfer.

The Commission's Submerged Aquatic Vegetation (SAV) Policy was developed specifically to address concerns about fishing gear damage to SAV-habitat. Although the policy addresses many other types of impacts to SAV, as well as a number of issues surrounding mitigation of these impacts, mitigation of fishing gear impacts is the area in which the Commission can have the most direct effect in protecting SAV. The SAV Policy charges the Commission to pursue this approach.

In October 1997, the Commission's Habitat Committee requested the Policy Board's assistance in completing the tasks of developing guidelines and standards for determining gear impacts to SAV, and identifying mitigation strategies. The Policy Board then remanded the issue to the Management and Science Committee (MSC). The MSC appointed a Work Group to prepare these guidelines and standards. The Work Group met in Alexandria, Virginia on September 29, 30 and October 1, 1998. Meeting participants included: Seth Barker (ME DNR), Peter Bergstrom (USFWS/Annapolis), Laura Ernst (RI Coastal Resources Management Council), Mark Fonseca (NOS Beaufort Lab.), Jon Kurland (NMFS, NE Region), Wilson Laney (USFWS/SAFCO), Jim Uphoff (MD DNR) and ASMFC staff Robin Peuser and Dianne Stephan. During the meeting, participants discussed key issues and developed guidelines and standards by consensus. This report was prepared based on the meeting discussions, a literature review, and input by experts in the fields of SAV ecology and fisheries management. The report was adopted by the ASMFC Management and Science and Habitat Committees at a joint workshop on November 2, 1999, and approved by the Interstate Fisheries Management Program Policy Board on February 9, 2000.

INTRODUCTION

The Atlantic States Marine Fisheries Commission's (ASMFC) interest in submerged aquatic vegetation (SAV) stems from the important role this habitat plays in critical life history stages of ASMFC managed species. Of the 24 species managed by ASMFC, over half of them derive benefits from association with SAV (Laney 1997). These benefits include shelter, increased availability of prey or food items, and spawning substrate. In addition to direct benefits to managed species, submerged aquatic vegetation also provides vital, irreplaceable ecological functions including chemical cycling, shoreline protection, and sediment stabilization, among others (Thayer *et al.* 1997).

Federally managed fisheries resources also rely on SAV, which has been identified as "essential fish habitat[1]" by the South Atlantic Fishery Management Council (SAFMC 1998) and New England Fishery Management Council (NEFMC 1998). Moreover, in the fishery management plan (FMP) for summer flounder prepared jointly by the Mid-Atlantic Fishery Management Council (MAFMC) and ASMFC, SAV was determined to be a "habitat area of particular concern[2]" for summer flounder (MAFMC and ASMFC 1998). Since SAV is an integral part of the Atlantic coastal ecosystem, all ASMFC and federally managed species rely on SAV to some unquantifiable degree.

In recognition of the importance of SAV, the Commission adopted a policy to protect SAV habitat in 1997 (ASMFC 1997). The goal of the policy is *"to preserve, conserve, and restore where scientifically possible, in order to achieve a net gain in SAV distribution and abundance along the Atlantic coast and tidal tributaries, and to prevent any further losses of SAV in individual states …"* The supporting documentation for the policy was presented in a volume outlining the significance of SAV as summarized above, and its susceptibility to human induced impacts (Stephan and Bigford 1997).

In its submerged aquatic vegetation policy, the Commission recognizes that most of the agencies that represent Commission member states do not have authority to regulate[3] habitat protection; rather, the focus of Commission member agencies is fisheries management. The policy is designed to overcome this limitation by encouraging collaboration between state habitat and fisheries management agencies to further protection of SAV. However, there is one particular category of human-induced impact to SAV for which the Commission and participating agencies do have regulatory jurisdiction -- impacts from fishing gears. The SAV policy directs the Commission to, *"in partnership with National Marine Fisheries Service and Fish and Wildlife Service, develop technical guidelines and standards to objectively determine gear impacts, and develop standard mitigation strategies."* This document is the culmination of that charge. The guidelines and mitigation strategies proposed herein, along with the SAV policy and supporting documentation, provide the necessary basis for addressing the impact of state fishing activities to SAV through the Commission's fisheries management program. The SAV policy further states that the Commission will consider the implementation of strategies to eliminate negative

---

[1] Essential fish habitat (EFH) is defined by the Magnuson-Stevens Fishery Conservation and Management Act (P.L. 94-265 *et seq.*) as "*those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.*"

[2] Habitat Area of Particular Concern (HAPC) is described in the EFH regulations as an area of EFH that meets any of the following criteria: provides an ecologically important function; is sensitive to human-induced degradation; may be stressed by development activities; or is rare [62 F.R. Vol. 244 §600.815(a)(9)].

[3] Marine fishery management agencies do have the authority and responsibility to offer comments on habitat impacts of federal projects under the Fish and Wildlife Coordination Act (P.L. 85-624 *et seq.*) and Coastal Zone Management Act (P.L. 92-583 *et seq.*).

impacts from fishing as FMP "compliance criteria"[4] when necessary to achieve the objectives of the SAV policy.

Impact to habitat from fishing gears is under increased scrutiny nationwide. The 1996 reauthorization of the Magnuson-Stevens Act, which regulates fisheries management in federal waters, includes provisions that require assessment of impacts to habitat from fishing gears used in "essential fish habitat," and mitigation of these impacts, to the extent practicable (P.L. 94-265 *et seq*.). The EFH regulations recognize the importance of evaluating the economic consequences that habitat protection measures might have on the regulated fishery, and integrating these considerations into the practicability assessment [64 F.R. Vol. 244 §600.815(a)(3)(iv)]. This assessment should also be undertaken when considering fishing impacts to SAV. When assessing the economic consequences of managing fishing gear impacts to habitat, the value of SAV must be determined on a coastwide basis. Although fisheries utilizing SAV-impacting fishing gears may contribute to a local economy, the fact that many species which derive benefits from SAV are pursued in coastwide fisheries must also be considered. Furthermore, SAV habitat serves vital, unquantifiable functions to the marine ecosystem as a whole.

Habitat degradation is generally agreed to be the most egregious threat to the long-term sustainability of fishery resources. From one perspective, it is most important in the sense that it is perhaps the least understood factor affecting fisheries productivity. Fishery managers recognize the significance of habitat and the ecosystem context of fisheries; however, they have yet to develop sufficient methodologies for integrating these concerns into operational protocols. In their summary of the effects of fishing on habitat, Auster and Langton (1999) conclude that the lack of information necessary for strategically managing fishing impacts on habitat emphasizes the need for implementation of a precautionary approach.

Implementation of a precautionary approach is especially pertinent for management of fishing gear impacts to SAV beds. The significance and importance of SAV to marine ecosystems in general, and ASMFC managed species in particular, is well established. The intent of the Commission to maintain current SAV abundance and strive for a net gain in SAV is clearly articulated in the goal of its SAV policy. This report will characterize the threat to SAV from certain fishing gears used in state waters. Based on existing information, the report determines that restoration of SAV is a more risky and costly alternative than impact avoidance. These factors strongly support the call for application of a precautionary approach in managing fishing gear impacts to SAV.

[4] Compliance criteria are management measures designated by a Commission FMP that are required to be implemented, under the Atlantic Coastal Fisheries Cooperative Management Act (P.L. 103-206 *et seq*.). Any state that fails to implement compliance criteria could be subject to a fishing moratorium imposed by the U.S. Secretary of Commerce.

APPROACH

A Commission Work Group was challenged to develop the guidelines and standards for determining gear impacts to SAV, and to identify mitigation strategies. The Work Group met in the Fall of 1998, and performed the rest of their deliberations via mail and telephone. During the meeting, participants discussed key issues and developed information to be included in this report by consensus. The report authors reviewed literature and consulted with additional experts on SAV, fisheries management, and fishing gear, and integrated the additional information into the final document.

Goal and Objectives

The following goal and objectives were identified by the Work Group for this project:

Goal: To identify methodologies to evaluate the impacts of fishing activities on the habitat value of submerged aquatic vegetation (SAV) and to develop standard strategies to mitigate (avoid, minimize, or compensate for) these impacts.

Objectives:

(a) To identify SAV life history requirements or ecological characteristics which may be susceptible to adverse impacts from fishing activity;

(b) To identify and characterize impacts or types of impacts to SAV from fishing activities or categories of fishing activities which frequently occur in state waters;

(c) To establish criteria for evaluating the significance of the effects of fishing activity on the habitat value of SAV;

(d) To identify and review common mitigation strategies, including their benefits and liabilities;

(e) To develop ecologically based criteria for mitigation strategy application.

This report closely follows the objectives outlined above. In the first section, SAV life history characteristics that are particularly susceptible to impacts from fishing gear are identified and summarized. Characteristics of common marine and brackish SAV are recorded. Instructions for determining boundaries of SAV-habitat are included along with this ecological background information, and state mapping programs are identified. This section also provides the ecological basis needed for understanding the adverse impacts that may result from fishing in SAV-habitat.

Potential impacts to SAV from fishing activities in state waters are reviewed in the second section of the report. Types of impacts to SAV are identified, and attributed to fishing gear commonly used in state waters. Criteria for evaluating the significance of impacts to SAV are determined, based on the goal of the Commission's SAV Policy. Propeller scarring was identified as a potentially severe impact associated with fishing. Since propeller damage caused by fishing and non-fishing vessels cannot be distinguished, an in-depth review of this impact and its mitigation strategies were excluded from this report. However, the issue is addressed briefly in the second section of the report.

In the third section of the report, common mitigation strategies are identified, along with their associated benefits and liabilities. Ecologically based criteria for application of these mitigation strategies are determined based on the first two sections of the report, and outlined in a decision tree for managers. A review of current state regulations that protect SAV from fishing gear is provided. Finally, additional considerations including research needs are outlined.

Economic consequences of applying mitigation strategies for fishing gear impacts to SAV are recognizably an important consideration. This report focuses on the evaluation of fishing gear impacts, identification of mitigation strategies, and ecological basis for mitigation. Further consideration of mitigation strategy application, including economic impacts and enforceability, may be addressed by the Habitat Committee in the near future.

SAV ECOLOGY AND LIFE HISTORY

DEFINITION OF SAV

As defined in the Commission's SAV policy (ASMFC 1997), SAV are "rooted, vascular, flowering plants (angiosperms) that, except for some flowering structures, live and grow below the water surface." This includes six species of marine seagrasses, as well as 20-30 species of freshwater macrophytes found in tidal freshwater and low salinity areas of all Atlantic coast states, with the exception of Georgia and South Carolina, where tidal amplitude and turbidity combine to inhibit their growth. Based on this definition, algae are not considered SAV. This report is limited in scope to tidal, estuarine, and marine ecosystems.

In the New England and northern mid-Atlantic regions, eelgrass (*Zostera marina*) dominates, and co-occurs with the cosmopolitan widgeon grass (*Ruppia maritima*). From North Carolina to the south, Cuban shoalgrass (*Halodule wrightii*) and *Zostera* commonly co-occur. In Florida, turtlegrass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) dominate along with Cuban shoalgrass and several species of *Halophila*, one of which (*H. johnsonii*) was recently listed as a threatened species (64 FR 49035) under the federal Endangered Species Act (P.L. 93-205 *et seq.*).

The brackish water communities can be quite diverse, with as many as 10 species of SAV co-occurring at a single location. Wild celery (*Vallisneria americana*), redhead grass (*Potamogeton perfoliatus*), sago pondweed (*Potamogeton pectinatus*), horned pondweed (*Zannichellia palustris*), and waterweed (*Elodea canadensis*) are a few of the native species that will dominate these areas while two non-native (exotic) species, milfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*), are also often present. Widgeon grass (*Ruppia maritima*) can tolerate both fresh and saltwater, and has the broadest range of all species (Orth, pers. com.).

The SAV policy acknowledges that there may be cases, such as with exotic species, where it may be appropriate to undertake management control measures. In such cases, the guidelines established in this report will not apply.

DETERMINING SAV DISTRIBUTION

The initial step of determining exactly what constitutes SAV in terms of spatial and temporal distribution -- in other words, determining the boundaries of SAV-habitat -- is critical. Distribution is usually identified in terms of beds rather than individual plants. Beds are comprised of individual plants which consist of an underground stem or rhizome that supports the above-ground shoot. Beds range from continuous to patchy in cover. Patchy cover poses the most difficult situation in determining SAV distribution and abundance. In general, the national mapping protocol (Dobson *et al*. 1995) supported by the Commission's SAV Policy should be applied when identifying or mapping SAV beds. A more risk averse approach to SAV conservation could be applied by identifying and conserving former and/or potential SAV habitat as well as areas where SAV are currently present. This section of the report will focus on problematic issues that have arisen in application of these protocols in patchy cover.

Patchy cover is often a result of physical environmental conditions, such as wave action and bottom type. It can also result from biological disturbance from bottom tending fish such as rays (Orth, pers. com.) A common misconception is that patchy cover provides less habitat value than continuous cover SAV beds. Patchy cover provides similar ecological functions as continuous cover (Thayer *et al*.

1997), and has been shown to provide important habitat for species such as spotted seatrout, blue crab, pink shrimp, black sea bass, Atlantic croaker, and southern flounder (Noble and Monroe 1991). Furthermore, Murphey and Fonseca (1995) found that patchy seagrass beds in North Carolina supported near equal densities of pink shrimp, had higher below-ground biomass, and had equal shoot densities when compared to continuous beds. A higher below-ground biomass could provide greater growth and/or recovery potential.

To further complicate this issue, patch distribution is often variable. Patches are dynamic, growing in one direction, retreating in another, producing seeds that form new patches nearby or sometimes distant from the parent patch. Monitoring studies of SAV distribution have shown that although specific patch locations change within an area, the overall percent of bottom coverage does not change (Fonseca *et al*. 1998). When defining the distribution of patchy SAV-habitat, it is important to include both the current location of SAV, and adjacent unvegetated areas. Knowledge of historical distribution is also useful in determining the appropriate extent of patchy SAV cover.

In contrast to patchy beds, some continuous bed margins have remained static for long periods of time (Fonseca, pers. observation). This phenomenon may be the result of intense biological sediment disturbance (Townsend and Fonseca 1998; Camp *et al*. 1973; Valentine and Heck 1991; and Valentine *et al.* 1994). However, fishing and boating activity that occurs along bed margins and results in intense physical disturbance of sediments is also a possible cause of static bed margins.

Defining Patchy SAV Distribution Using Survey Data - It would be difficult, costly, and impractical to identify the distribution and boundaries of "very" patchy SAV. Taking this into account, the following definition for determining SAV distribution was agreed upon by the Work Group for use in this effort*: A SAV bed includes SAV of patchy distribution at 10% or greater bottom coverage calculated over an area of ¼ hectare at 1 meter resolution using direct ground observation, or at any [detectable] percentage of bottom coverage calculated over an area of 1 hectare at 10 meter resolution, using aerial photography from 12,000 feet*. Literature supporting these definitions include Fonseca and Bell (1998), Fonseca *et al.* (1998), and Fonseca *et al.* (in review).

Defining Patchy SAV Distribution Without Survey Data - For marine SAV, evidence suggests that a patch must be maintained by a surrounding unvegetated area of at least twice the patch size (Fonseca *et al.* 1998). However, given enough time, it is probable that all presently unvegetated spaces among seagrass patches would be colonized, doubling the existing patch area. A more conservative definition of patchy seagrass habitat could provide significant ecological benefits. Repeated surveys over time provide more detailed information regarding the size and location of bottom area needed to maintain a patch. If survey data are not available, the estimate of bottom area that is twice the amount of the currently vegetated bottom should be used in order to allow for movement of patches and inter-patch colonization. This methodology represents recommended minimum standard measures, and should be used whenever insufficient resolution of survey data exists.

Although the methods for determining patchy distribution with and without survey data are based on the best scientific information available, further research is needed to ensure the comparability of results between the different methods of determining SAV distribution. The current status of mapping by state is given in Table 1.

Table 1. Status of SAV mapping in Atlantic coast states, as provided by state contacts.

STATE	STATUS OF MAPPING	GIS	CONTACT
ME	Completed in 1999, Electronic version available in 2000. Monitoring planned for 10-year cycle (funding dependent). **Funding sources**: State of ME, NOAA Coastal Zone Management	Yes	**Seth Barker**, ME Dept. of Marine Resources., 207/633-9507, seth.barker@state.me.us
NH	Eelgrass in Great Bay and Little Harbor mapped by University of New Hampshire. Piscataqua River eelgrass mapped in conjunction with ME Dept. of Marine Resources. Funding needed for offshore areas, Rye Harbor, and the Hampton Estuary. **Funding sources**: State of NH, EPA, NOAA and U.S. Navy.	Yes	**John Nelson,** NH Fish and Game, 603/868-1096
MA	100% mapped during 1994-97. Data available at www.state.ma.us/mgis/ or www.noaa.csc.gov. 3-year coastal trend analysis completed in 2002 and available on websites as developed. **Funding sources**: MA Dept. of Env. Protection; NOAA C-CAP, and MA Coastal Zone Management.	Yes	**Charles Costello**, MA Dept. of Environmental Protection 617/ 292-5907, charles.costello@state.ma.us
RI	Completed GIS maps of eelgrass beds for Narragansett Bay based on 1996 aerial photography. Developing a supplemental GIS point coverage of sites not previously identified in the bay with Division of Fish & Wildlife. Use of 1999 aerial photography to complete the statewide inventory of eelgrass beds is underway in the South Shore, Little Compton, and Block Island. **Funding sources**: U.S. EPA, RIDEM Aqua Fund and Narragansett Bay Estuary Programs, Save The Bay, Inc., & R.I. Oil Spill Prevention, Administration & Response Fund. Shoreline surveys - completed for portions of Narragansett Bay and several coastal ponds in RI by the RI Department of Environmental Management Fish and Wildlife and the RI Coastal Resources Management Council	Yes	Narragansett Bay mapping: **Helen Cottrell**, Narragansett Bay Estuary Program, 401/222-4700 x7273 Shoreline surveys: **Laura Ernst**, 401-222-2476 (CRMC), Chris Powell, 401-294-4524 and Art Ganz, 401-783-2304 (RIF&W).
CT	Lower Connecticut River (area from Cromwell south) completed in 1997. Long Island Sound eelgrass mapped in 1993-5 by University of Connecticut and DEP's Long Island Sound Resource Center**. Funding sources:** State of CT Long Island Sound Research Fund.	Yes	**Ron Rosza** CT Dept. of Environmental Protection (DEP), 860/424-3034, ron.rosza@po.state.ct.us
NY	Aerial photographs of Long Island estuaries and Hudson River are archived by NY Dept. of Environmental Conservation (DEC) Bureau of Marine Resources. Data analysis and production of GIS coverages for Hudson River will be completed in 2001. Hudson River SAV mapping and function definition is a cooperative project among NYS DEC, Cornell University, and the Institute of Ecosystems Studies**. Funding sources**: State of New York, NOAA	Yes	**Fred Mushacke,** NYS Dept. of Env. Conserv. (DEC) 631/444-0465, fmmushac@gw.dec.state.ny.us Additional contacts: **Dave Fallon,** NYS DEC, 631/444-0464 Hudson River Contact: Chuck Nieder , NYS DEC, 914/758-7013 wcnieder@gw.dec.state.ny.us
NJ	Seagrasses in New Jersey were mapped in 1979 by the Department of Environmental Protection, through contract with Earth Satellite Corp. In 1988, seagrasses in Barnegat Bay and Little Egg Harbor were mapped by the Division of Fish, Game and Wildlife. **Funding sources:** The 1979 mapping conducted with NOAA funding through the DEP's Division of Coastal Resources. 1986-87 project conducted with equal state and federal funding.	No	**James Joseph**, NJ Division of Fish & Wildlife, (609) 748-2040 Jjoseph@dep.state .nj.us
DE	SAV in marine tidal areas mapped. Plan to convert data (currently in latitude and longitude) to GIS format.	No	**Ben Anderson**, DE Natural Res. & Env. Control, 302/739-4590, Ben@state.de.us

STATE	STATUS OF MAPPING	GIS	CONTACT
MD	Completed with annual updates. Data available via website: http://www.vims.edu/bio/sav/index.html **Funding sources:** EPA, VA Dept. of Env. Quality, Virginia Institute of Marine Science (VIMS), MD Dept. of Natural Resources (MDDNR), NOAA, US F&WS, Allied Signal	Yes	**Mike Naylor**, MD Dept. of Natural Res., 410/260-8652, MNAYLOR@dnr.state.md.us Survey contact: **Robert Orth,** VIMS, 804/684-7392, jjorth@vims.edu
VA	Completed with annual updates. Data available via website: http://www.vims.edu/bio/sav/index.html **Funding sources:** EPA, VA Dept. of Env. Quality, Virginia Institute of Marine Science (VIMS), MD Dept. of Natural Resources (MDDNR), NOAA, US F&WS, Allied Signal	Yes	**David Bower**, VMRC, 757/247-8063, Dbower@mrc.state.va.us Survey contact: **Robert Orth,** VIMS, 804/684-7392, jjorth@vims.edu
NC	High salinity SAVs between Beaufort and Hatteras Inlets have been mapped by NOAA. Portions of estuarine areas have been mapped by the NC Geodetic Survey. The DMF is mapping estuarine bottom types and shellfish beds for the entire coast, excluding the open waters of Pamlico Sound. This project is estimated to be completed by 2001. There are not any plans to map seagrasses in the open waters of Pamlico Sound. Data are in GIS format. **Funding source**: NC state legislature.	Yes	**Randy Ferguson**, NOAA, 252/728-8764 **Craig Hardy**, NC Division of Marine Fisheries, 252/726-7021
FL	All of Florida's seagrasses have been mapped at one time or another by a myriad of agencies, including the various water management districts, the state Fish and Wildlife Conservation Commission (FWC), the U.S. F&WS, and NMFS. The FWC has developed a GIS database including all seagrass mapping efforts. This database will be continually updated as time and funding permit. Database available via website (http://www.dep.state.fl.us) after January 2000. **Funding sources**: state water management districts, state of Florida, EPA (SWIM programs), USGS, NOAA	Yes	**Stu Kennedy**, FL FWC 727/896-8626, stu.kennedy@dep.state.fl.us Mapping Contact: **Henry Norris**, FL FWC Commission, 727/896-8626, norris_h@epic7.dep.state.fl.us

KEY LIFE HISTORY REQUIREMENTS AND ECOLOGICAL CHARACTERISTICS

General characteristics of SAV are discussed in the synthesis papers contained in the Commission's SAV background document (Stephan and Bigford 1997). It is especially important to consider certain specific characteristics of SAV here, since these characteristics may influence SAV susceptibility to damage or loss from fishing gear impacts. The importance of these features vary among species and geographic location. The characteristics of concern include light requirement, asexual reproductive structures (also called growing tips or meristems), reproductive structures (flowers and seeds), and ability to recover from disturbance or injury. An additional factor that can affect SAV susceptibility to physical damage is the substrate type in which the SAV is found.

Light

Like all plants, SAV have specialized structures within their leaves that use light energy to convert water and carbon dioxide into food. Light availability is often a factor limiting SAV distribution. SAV have high incident light (subsurface light reaching the sediment) requirements which vary among species. Marine SAV require a minimum of 20% incident light (Kenworthy and Haunert 1991). Brackish water species require approximately 13% incident light (Batiuk *et al*. in press). *Zostera* in Chesapeake Bay has a minimum light requirement of 23.9% (Batiuk *et al*. 1992).

Algae require only 2% incident light to maintain photosynthetic processes, and are much more successful competitors than SAV in turbid, light-limited waters. Turbidity from suspended sediments can be the result of natural processes such as storms, or can be produced by boat wakes and/or bottom-tending mobile fishing gear. Moreover, excess nutrients from polluted runoff, failing septic systems, or boat discharges can stimulate phytoplankton blooms, which in turn increase water turbidity and decrease available light to SAV, resulting in loss of SAV habitat. Excess nutrients also stimulate epiphytic growth on SAV that can further decrease available light because of shading.

Vegetative Growth/Asexual Reproduction

Like all vascular plants, SAV have specialized tissues that are capable of growth, called "meristems" (Figure 1). Meristems are often seasonally active, and are responsible for plant growth and vegetative propagation/asexual reproduction. For example, meristems found at the ends of rhizomes create "runners" which allow the plant to spread throughout the sediment, and produce plants beyond the stem of the parent plant (a form of vegetative propagation/asexual reproduction). Most rhizome meristems of marine SAV are located underground.

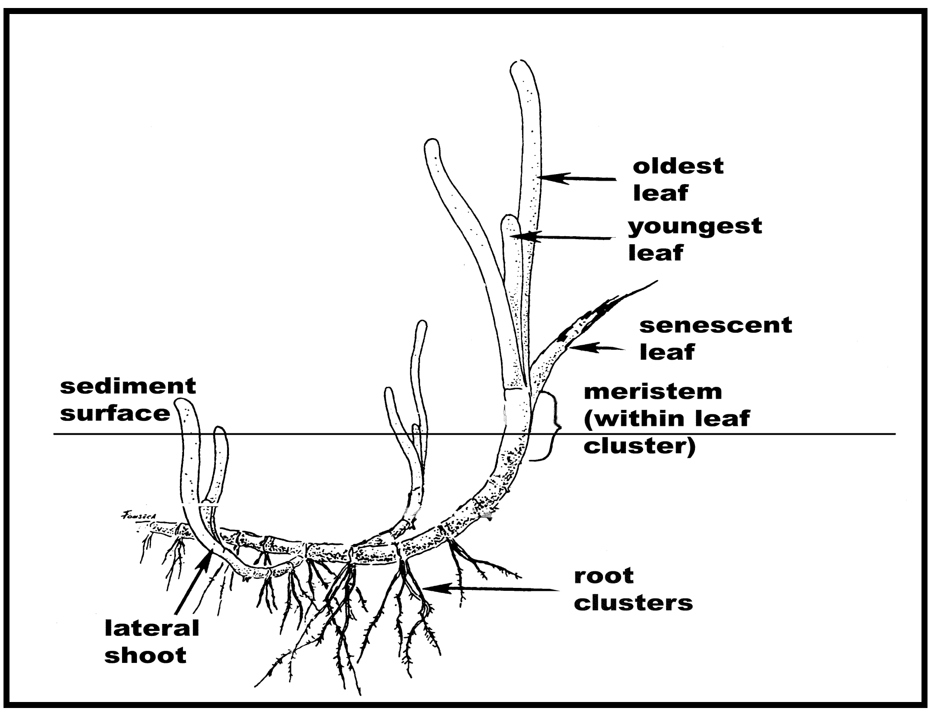


Figure 1. Major features of the morphology of *Zostera marina* (adapted from Thayer *et al.* 1984)

For our purposes, we will consider two basic meristem types, basal and apical. Basal meristems can be found at the base of leaves, while apical meristems can be found at the tip of rhizomes or on the stem. The location of meristems with regard to the sediment-water column interface (above or below ground) varies by species, although meristems on the stem are found above ground. In most cases the *location* of the meristem rather than the *type* is of primary concern when determining fishing gear impacts and the ability of the SAV to recover. However, the presence or absence of basal meristems is also an important factor to consider, especially in the case of leaf shearing (see "Impacts from Fishing Activities—Leaf Shearing").

Meristems are vulnerable areas because damage to them can seriously compromise the plant's ability to grow and reproduce asexually for an entire growing season, or even result in death. The difference in meristem location on the plant, growing season, and depth below the sediment surface in addition to the type of sediment in which the SAV is found affect a plant's vulnerability to injury. SAV whose growth and vegetative reproduction is primarily from below-ground meristems are usually less vulnerable to above-ground damage. Plants whose growth and vegetative reproduction are focused in the water column (e.g. *Pomotageton*) are more vulnerable to above-ground disturbance. Information regarding asexual reproduction for common marine and brackish water SAV is given in Table 2.

Sexual Reproduction

Some species of SAV use sexual reproduction to colonize new areas and/or maintain existing distributions. SAV reproduce sexually through flower and seed production. In some cases, a plant produces only female or male flowers, in other cases, a plant produces both types of flowers, and in still other cases a plant produces perfect flowers with both male and female reproductive structures. Some species rely heavily on successful sexual reproduction and seed setting for producing the next year's plants (e.g. *Halophila decipiens*, annual forms of *Zostera marina)*, while other species rely on both sexual and asexual reproduction for future growth. Injury to reproductive structures of plants that rely heavily on sexual reproduction is perhaps a more serious impact than for plants with both types of reproduction. Also, disturbance of the sediment, particularly during winter months, may disrupt SAV seed banks with potentially serious impacts on the subsequent growing season.

Table 2. SAV life history information and characteristics important for determining potential impacts from fishing gear (Carter and Rybicki 1985; Carter pers. com.; Fonseca *et al*. 1998; Hurley 1991; Kantrud 1990; Kantrud 1991; Kraemer *et al.* 1999; Naylor, pers. com.; Thayer *et al.* 1984; and Tiner 1987).

SPECIES & ATLANTIC DISTRIBUTION	GROWTH AND REPRODUCTION	PLANT AND BED STRUCTURE	ECOLOGY
<u>Zostera</u> <u>marina</u> - eelgrass Maine through North Carolina	Perennial or annual; sexual and vegetative reproduction. Vegetative reproduction via creeping rhizome. Basal meristems present. Chesapeake Bay (CB) and areas north: sexual reproduction in spring through early summer (through early fall in New England); seed germination during fall; greatest vegetative growth spring and fall. South of CB: Vegetative reproduction October – June; Sexual reproduction December – April.	Very large variation in leaf size ranging from 30 –200 cm. Flowers and seeds closely associated with leaves. Rhizomes rarely deeper than 5 cm. As an annual, every shoot flowers, producing a high flowering shoot density.	Most common temperate seagrass; found in high energy waters. Severe decline (90%) along the Atlantic coast during the 1930s from wasting disease; some areas in northeast have still not recovered. Decline had a devastating impact on brant geese population in Chesapeake Bay region and on bay scallop populations. North Carolina – dominant from winter to summer. Evidence for increased flowering associated with disturbed sites (e.g. intertidal areas) and extreme salinity. Occurs in up to 10 m of water in New England areas.
<u>Ruppia</u> <u>maritima</u> - widgeon grass Maine through Florida	Vegetative reproduction via creeping rhizome. April – October. Basal meristem present. Sexual reproduction – spring through summer; Late summer in Chesapeake Bay.	Produces extensive flowering stalks often reaching a meter in length, with numerous seed clusters. Flowers at water surface.	Can grow in both fresh water and hypersaline conditions (>70 ppt). Favorite food of migratory waterfowl.

SPECIES & ATLANTIC DISTRIBUTION	GROWTH AND REPRODUCTION	PLANT AND BED STRUCTURE	ECOLOGY
Halodule wrightii – Cuban shoalgrass North Carolina through Florida	Vegetative reproduction - April through October in NC; year-round in FL. Basal meristem present. Sexual reproduction – spring through summer.	Flowers occur on base of shoots near sediment surface. Rhizomes fairly shallow, rarely deeper than 5 cm. Rhizomes may extend into water column with attached short shoots that are thought to be a form of vegetative reproduction. Leaves are strap-like with blade length range from 5-40 cm. Forms dense beds (>5,000 shoots per m^2).	Can occur in very shallow water and is noted for its relative tolerance to desiccation once rooted. Forms pancake-like patches reaching 30 m diameter or extensive meadows on shallow shoals, experiencing regular exposure at low tides. Dominates mid-summer through early fall in NC.
Syringodium filiforme - manatee grass Florida	Vegetative reproduction via creeping rhizome year round. Basal meristem present. Sexual reproduction – spring through summer.	Produces long, nearly round, erect blades. Rhizome system varies in depth from 1-10 cm. Flowering produces extensive branching extending up into the water column.	Beds often accumulate a large understory of unattached macroalgae. Tends to occur in deeper waters.
Thalassia testudinum - turtlegrass Florida	Vegetative reproduction via creeping rhizome year-round. Basal meristem present below sediment surface. Sexual reproduction – spring through summer.	Leaf length varies from 10-75 cm depending on water depth. Leaf is strap-like with wide blade often >1 cm. Leaves emerge from sediment at top of a vertical rhizome that rarely protrudes above sediment surface. Thick rhizomes from which individual shoots originate are often located 20 cm or more deep. Flowers emerge from sediment adjacent to short shoot. Forms dense, extensive stands.	Favorite food of endangered green sea turtle. Known for its longevity, individual plant shoots can live >10 years. Lowest asexual reproduction rate of all Atlantic marine SAV. Seeds have been successfully used in planting.

SPECIES & ATLANTIC DISTRIBUTION	GROWTH AND REPRODUCTION	PLANT AND BED STRUCTURE	ECOLOGY
Halophila decipiens – paddlegrass **H. engelmanni – stargrass** **H. johnsonii – Johnson's seagrass** Florida	Vegetative reproduction via creeping rhizome spring through fall. Basal meristem present. Sexual reproduction summer through fall. *H. decipiens* relies heavily on seeding for survival. *H. engelmanni* may be perennial. Sexual reproduction in *H. johnsonii* may proceed without fertilization.	Extremely fragile seagrass. Strap-like leaves with short blades 10-25 mm in length. Can be easily dislodged from the sediment. Susceptibility to disturbance offset by high fecundity and vegetative reproduction rates. Plants cannot tolerate burial and will disintegrate within 24 hours of burial.	Can withstand very low light conditions ~6% of insolation. Occurs at great depths (>40m) or in shallow turbid waters, under docks or as an understory to other seagrass species. *H. johnsonii* is listed as threatened under the Endangered Species Act.
Vallisneria americana – wild celery Maine through Florida	Vegetative reproduction via rhizomes and tubers. Basal meristems present. Sexual reproduction documented. Chesapeake Bay: Sexual reproduction August through September; seed dispersal in fall.	Extensive root and rhizome system. Male flowers located on short stalk near base of plants; female flowers on long stalks at water surface. Seeds develop in pods under water. Strap-like leaves.	Tolerant of wave action and currents. Usually found in coarse silt to sandy/gravelly soil. Often considered freshwater, but very tolerant of saline conditions up to 10-15 ppt; found in upper reaches of estuaries. Excellent food value for waterfowl.
Potamogeton perfoliatus – redhead grass Maine through Florida	Vegetative reproduction via tubers and resting buds. Basal meristem absent. Sexual reproduction documented. Chesapeake Bay – sexual reproduction July-Sept.; seed dispersal in early Fall.	Extensive root & rhizome system. Flowers develop in apical stems near water surface	Often found in quiet waters and firm muddy soils. Fairly tolerant of wave action and currents. Usually considered freshwater, but very tolerant of saline conditions; found in upper reaches of estuaries. Good food value for waterfowl.

SPECIES & ATLANTIC DISTRIBUTION	GROWTH AND REPRODUCTION	PLANT AND BED STRUCTURE	ECOLOGY
<u>Potamogeton</u> <u>pectinatus</u> – sago pondweed Maine through Florida	Vegetative reproduction via rhizomes and tubers at leaf axils which break off, overwinter, and form new plants in Spring. Basal meristems absent. Apical meristems present. Sexual reproduction - less important because of low germination rate. Chesapeake Bay – Sexual reproduction in June-July; seed disperal in late summer and fall.	Long rhizomes & below-ground runners provide strong anchorage to substrate in silt/mud. Flower spikes at water surface.	Often considered freshwater, but very tolerant of saline conditions up to 20 ppt; found in upper reaches of estuaries. Most abundant in Chesapeake Bay and Northwestern U.S. Excellent food value for waterfowl.
<u>Elodea</u> <u>canadensis</u> – waterweed Maine through North Carolina	Basal meristems absent. Sexual reproduction – July-September.	Stems many-branched, often forming dense masses. Male and female flowers born on stalks from leaf axil; male stalks longer than female.	Brackish, tidal fresh, and inland waters.
<u>Zannichellia</u> <u>palustris</u> horned pondweed Maine through Florida	Basal meristems absent. Sexual reproduction – July – October. Chesapeake Bay – Sexual reproduction in March-May.	Stems very slender, fragile, and branched. Minute flowers in leave axils enclosed by a sheath.	Brackish, tidal fresh and inland waters.

In marine species, flowers are generally produced on the shoots, often rising above the leaf portion of the plant and reaching to the water's surface to facilitate pollination. Flowers of brackish water species usually occur at the leaf/stem junction (axil). Thus, flowers can be exposed to impacts that the non-flowering parts of the plant are not. For example, eelgrass flowers are produced on stalks that rise above the rest of the plant, in some cases by 3 feet. These characteristics are further described for some SAV species in Table 2. Factors characterizing the vulnerability of SAV sexual reproduction to gear impacts include seasonality, flower location and hardiness, seed setting, and seed germination.

Substrate Type

Sediment or bottom type can influence SAV vulnerability to fishing activities and/or ability to recover from injury, as demonstrated in Fonseca *et al.* 1984, which investigated impacts to SAV from bay scallop dredging. In general, more damage from dredging occurred to SAV located in soft bottom sediment (mud) than hard bottom sediment (sand). In softer sediments, plants were dug up, and damage to the underground plant tissues occurred, including meristems. In a harder bottom type, damage was found to be relatively greater to above-ground parts, and underground meristems were left intact and able to begin to repair shoots or produce new ones after impacts had ceased. However, repeated above-ground damage to SAV in sandy bottom will almost certainly produce a decrease in SAV biomass and/or distribution over time.

Recovery

SAV species exhibit a wide range in ability to recover from injury. Many of the ecological characteristics already discussed influence species recovery potential. Location of meristem and sexual reproductive structures are of primary concern, as injury to these structures may effect the plant's ability to replace damaged tissues or lost plants. For species that rely on seed set and successful germination, beds tend to recover more rapidly (1-2 growing seasons). For species that rely on vegetative encroachment, bed recovery can take many years (Fonseca *et al*. 1998). Recovery ability is also influenced by the magnitude or extent of the injury, the location and amount of any stored energy reserves in the SAV plant, seed or tuber set prior to disturbance, and local environmental hydrodynamics.

Since recovery must take into account so many different factors, there is very little quantified information available. Studies that have investigated some of the factors affecting recovery for different species are summarized below. In order to provide fisheries managers with useful information on the ability of SAV to recover from injury, estimates of recovery potential were developed for SAV species by the Work Group and other experts. Based on the studies discussed below and the Work Group's experience with SAV species, a qualitative evaluation of the relative ability of certain SAV species to recover from injuries to growth and reproductive features is presented in Table 3. The overall intrinsic injury recovery potential is then estimated based on this information.

Recovery potential for injury to meristems was determined to be high in Table 3 if a species has relatively high asexual growth potential, such as that exhibited by *Halodule* in numerous restoration experiments. In contrast, *Thalassia* was ranked low in this category because asexual reproduction is relatively slow. Very little is known about sexual reproduction in *Halodule,* and that information which is available suggests its ability to reproduce sexually is very low. The overall recovery potential for *Halodule* is ranked "high" despite the low potential reovery based on sexual reproduction because studies have shown it to have consistently high natural asexual reproduction (spreading) and it has performed very well in restoration experiments.

Ruppia is ranked overall with the same score as *Halodule*, even though the asexual recovery potential for *Ruppia* was ranked "moderate" and the sexual recovery potential was ranked "high" based on this species' reliance on seedlings to generate new populations every year. These seedlings are somewhat vulnerable to disturbance. In contrast, *Halodule* regenerates each year from rhizomes lodged firmly in the sediment. The relative strengths and weaknesses in these two species' recovery potentials seems to leave them co-equal.

Research that could be applied in the area of recovery includes a study on the effects of turtle grazing on the seagrass *Thalassia* in St. Croix. Greenway (1974) concluded that *Thalassia* leaves could be cropped up to six times per year based on leaf regrowth. This study also found a significant decrease in plant biomass at the 5th harvesting, and associated decreased leaf width of *Thalassia* with stress from heavy grazing pressure. Overall, then, *Thalassia* is considered to have a very low recovery potential (Table 3).

Peterson et al. (1987) found that recovery of *Zostera* and *Halodule* biomass from two intense clam-kicking treatments did not begin until more than two years after the impact terminated. When compared with controls four years later, biomass was still about 35% lower than expected. However, in raking and light clam-kicking treatments, biomass decreased by 25% immediately compared to controls, and then recovered fully within a year.

Table 3. Work Group and expert estimates of relative ability of SAV species to recover from injuries to key features (meristems and reproductive structures) and overall estimates for injury recovery potential.

SPECIES	Injury Recovery Potential		Overall Intrinsic Injury Recovery Potential
	Asexual (injury to meristems)	Sexual (injury to reproductive structures)	
***Zostera marina* (eelgrass)**	Moderate	Moderate & variable	Moderate
***Halodule wrightii* (shoalgrass)**	High	Low	High
***Ruppia maritima* (widgeon grass)**	Moderate	High & variable	High
***Thalassia testudinum* (turtlegrass)**	Low	Low & variable	Low
***Syringodium filiforme* (manatee grass)**	Moderate	Moderate	Moderate
***Halophila* spp.**	High	Very high	High
***Vallisneria americana* (wild celery)**	Low	High	Moderate
***Potamogeton perfoliatus* (redhead grass)**	Moderate	Moderate	Moderate
***Potamogeton pectinatus* (sago pondweed)**	Moderate	Moderate	Moderate
***Zanichellia palustris* (horned pondweed)**	High	High	High
***Elodea canadensis* (common elodea)**	High	High	High

An important point to note is that while SAV is recovering, interim resource services are lost. In other words, SAV does not provide the function or degree of function that was provided prior to the injury—functions such as primary production, habitat for fish and shellfish species, sediment stabilization, and filtering. In fact, recovery to 100% of the pre-impact resource services may not occur if significant alteration of the benthos has occurred. Recovery of interim lost services are regularly sought by the National Oceanic and Atmospheric Administration under natural resources damage assessment claims.

IMPACTS FROM FISHING ACTIVITIES

INJURY TYPE

Impacts to SAV from fishing gear are primarily due to mechanical damage from bottom-disturbing fish harvesting techniques. The types of damage that can result include physical disturbance such as leaf shearing, flower/seed shearing, crushing, chopping, and/or dislodging; and impacts from suspended sediments such as burial and stress from shading associated with increased turbidity. Injury could also result from any combination or cumulative effects of these impacts.

Physical Disturbance to Plants

The Work Group identified physical disturbance or damage to SAV plants as the injury of primary concern when considering impacts from fishing gear. These injuries include direct damage to plant parts or total uprooting of plants. Seriousness of impact depends in part upon whether the disturbance is below ground or above ground in nature.

A common misconception is that shearing of SAV leaves or disruption of the sediment is beneficial to the survival and maintenance of SAV beds. On the contrary, research findings demonstrate the opposite to be true and based on the Work Group's knowledge there are no data to suggest that mechanical perturbation is required or beneficial. Moreover, dislodged marine plants will rarely re-root themselves.

Leaf Shearing – When fishing gear is dragged over SAV, "leaf shearing" or cutting of leaves distal to or at the leaf/stem junction can result. Once a leaf is sheared, the plant cannot regrow the lost portion of the leaf, although the plant can produce a new leaf by stimulating growth from undamaged meristems.

Leaf shearing is thought to be more limiting for SAV with above-ground meristems, since activities that cause leaf shearing could shear off the meristem as well. In particular, SAV species such as *Potamogeton*, which rely on apical meristems, are thought to be more susceptible to above-ground impacts (CBP 1995, Goldsborough 1997). In the case of leaf shearing, some brackish SAV can re-grow leaves from their stems if carbohydrate reserves are sufficient and meristems are undamaged. In brackish water species, lower leaves are often sloughed off as shading from the canopy increases (Carter pers. com.).

It is important to remember that to accomplish replacement growth, energy must be diverted from other functions. In the meantime, the nursery or sheltering capacity of the lost leaves are also lost as well. In general, limited leaf shearing will not cause plant death; however, repeated leaf shearing could have a significant impact and result in plant death and loss of SAV-habitat.

Seed or Flower Shearing – Bottom tending mobile fishing gear can also result in flower and seed shearing which can impact the plant's ability to reproduce. If disturbance occurs at a time when the seeds are mature, the activity could be beneficial for seed dispersal; however, this possibility requires further study to determine its feasibility and impact. Loss of flowers or seeds will affect the next year's growth of new plants. This impact would likely be most detrimental for species that rely heavily on sexual reproduction (*e.g. Zostera marina*).

Uprooting – In the context of this report, uprooting includes inconsistent, occasional snagging and dislodging of plants, without significant disruption to sediments. Uprooting differs from the following category of Below-Ground Impacts in the method of disruption. Uprooting is caused by incidental snagging resulting from gears such as haul seines which drag across the surface of the sediments, and occasionally snag a plant and pull it out by its roots. Gears which cause below-ground impacts dislodge plants by way of digging into the sediments.

Below-Ground Impacts - Fishing activity that results in digging up plants, severe disruption of the sediments and roots and damage such as crushing or chopping underground structures will seriously damage these structures and result in plant death and loss of SAV habitat. The disturbance causes serious damage to underground roots, rhizomes, and meristems. Meristems are essential for the plant's continued growth and survival. Roots and rhizomes are essential for nutrient uptake, and anchorage to the substrate.

Below-ground damage can also result from the propeller or hull of a vessel making contact with SAV and/or the substrate below, particularly if operated through a SAV bed in shallow water. Impacts can be most severe at low tide. The damage results in characteristic cuts/trenches referred to as propeller or "prop" scars. This below-ground damage is significant in that it completely disrupts the sediments and/or dislodges the SAV, although the impact is limited in width to the size of the propeller and length of the boat trail. Aerial photography from Florida Keys shows that prop scarring can be a very serious problem (Sargent *et al*. 1995) especially when *Thalassia* is involved—it can take more than 5 years to recolonize a prop scar (Zieman 1976) and at least 17 years for deeper scars (Fonseca, unpublished data).

Unfortunately, it is usually impossible to differentiate between prop scars caused by fishing and non-fishing vessels. Therefore the guidelines presented in this report will only address the impact of propeller scarring in the context of "clam kicking" - a fishing technique which uses boat propellers to dig out quahogs.

Burial - Above-ground parts of SAV—shoots, leaves and flowering structures—can be buried by sedimentation associated with bottom disturbance from trawling, dredging or boat propellers. Shoots and leaves bend under the rapid cascade of sediment, becoming completely buried with as little as a few centimeters of settled material (Fonseca 1992). Once buried, the leaves can no longer function, which diminishes the plant's ability to grow and reproduce. *Halophila* is especially susceptible to plant loss from this impact, and its leaves will disintegrate within 24 hours of burial. The tubers of certain brackish water species can withstand burial to fairly large depths (Carter and Rybicki 1985). Fixed gear such as pots or traps can also cause this type of impact, especially when left in place for an extended period of time.

Turbidity

Turbidity is a measure of water clarity, and is determined by the transmission of light through the water column. Increased turbidity reduces the amount of light available to SAV for photosynthesis. As previously discussed, turbidity will significantly impact marine SAV when it reduces incident light levels to less than 20%, and brackish water species when incident light falls below 13% (Batiuk *et al*. in press). Increased turbidity results mostly from bottom-disturbing fishing activities. Data to quantitatively assess the impacts on turbidity from most fishing gear activities is currently unavailable. The effects of hydraulic clam dredging on turbidity in Chesapeake Bay were researched by Ruffen (1995). Changes in turbidity were found to be affected by sediment size and water depth. Turbidity increases were of the magnitude that could adversely impact SAV; however, turbidity returned to background levels in less than a day. Long-term impacts were not investigated.

Cumulative Impacts

If SAV experiences impacts from multiple sources such as leaf-shearing and increased turbidity, the stress of multiple impacts is expected to make the plant more susceptible to injury from either or both impacts.

SOURCES OF IMPACT

Fishing Gears

The Work Group determined that fishing gear impacts to SAV should be evaluated on a gear-by-gear basis. Gears currently used in state estuarine waters and SAV beds are identified for each Atlantic coastal state in Table 4. Each of these gears known to be used in SAV is described below, along with any scientific studies that have investigated the habitat impacts of the gear. The Work Group applied the results of these studies, and extrapolated where necessary to determine the impacts associated with gear types of concern (Table 5).

Trawl – A trawl consists of a funnel shaped net that is pulled behind a vessel, with varying attachments to keep the net open, depending upon the type of trawl. Most trawls used in state waters are bottom-tending otter trawls. Bottom-tending means that the bottom of the trawl drags along the sea floor. Otter boards or "doors" are used as horizontal planers to keep the mouth of the net open. The footrope runs along the anterior bottom portion of the net, and can also be preceded by a sweep. Either the footrope or sweep can be outfitted with cookies or rollers that function by rolling and guiding the net over uneven bottom. Sometimes the net portion of the gear is preceded by a "tickler" chain which runs between the ends of the footrope, and functions by dragging along the bottom just in front of the net, scaring bottom dwelling fish & organisms up and into the net. Fish, shrimp, or other sea life are captured by the net and collect in the posterior or "cod" end of the net. Habitat impacts from otter trawls occur when the bottom of the net, sweep, and/or doors drag along or dig into the sea floor.

A beam trawl is much like an otter trawl, except the net is spread horizontally by a wooden or steel beam. The trawl net is spread vertically by heavy steel trawl heads that have skid-type devices with a heavy shoe attached. The headrope is fastened directly to the beam and the groundrope is connected loosley between the shoes. Beam trawls may also be fitted with tickler chains or a chain mat. Beam trawls are purported to be more effective at catching demersal species (Sainsbury 1996).

Numerous studies have investigated the physical impact of trawl parts (tickler chain, otter boards, net) and different types of trawls on the sea floor (Bridger 1972; Brylinsky *et al.* 1994; de Groot 1984). A review of this type of literature and further communication with scientists and fishermen estimated the maximum cutting depth for otter trawl doors and beam trawls to range between 0.05 and 0.3 m when used in depths over 30 m (Drew and Larsen 1994). The variation in values was attributed to gear weight, bottom hardness, and towing warp (force on gear) to depth ratio. Trawl doors were found to penetrate the surface more than the rest of the gear. In estuarine waters, a study of lobster trawling gear in Long Island Sound found trawl door penetration values of approximately 0.05-0.15 m (Smith et al. 1985). Furrows from trawl gear in Naragansett Bay were found to be relatively short-lived in shoal waters and sand sediments, but longer lived in deepwater mud habitats (DeAlteris *et al.* 1999)

Mediterranean studies have concluded the loss of *Posidonia* meadows is due to trawling impacts (Ardizzone et al. 2000; Ardizzone and Pelusi 1983; Guillen *et al*. 1994). *Posidonia oceanica* is a seagrass that grows in waters deeper than most North American species, and in a manner similar to *Halodule*, with basal meristems and runners near the surface during asexual reproduction.

In a review of potential impacts of fishing gear on habitat in the Gulf of Mexico, Barnette (1999) ranked impacts of otter trawls on SAV as "significant." The cited studies were limited to one account of impacts to *Posidonia* (Guillen et al 1994), which was inconclusive; and Berkeley *et al.* 1985 which investigated the Florida bait shrimp (beam trawl) fishery. Meyer *et al*. (1999) showed that gear modifications in this fishery especially designed to minimize damage to SAV can have little impact on non-flowering *Thalassia* beds. The gear used in this study was a 3.4 m, 75 kg beam trawl modified with a slotted roller along the entire lower portion of the frame. The study did not assess possible damage to

Thalassia sexual reproduction. Repetitive disruption of beds in the summer has the potential to damage reproductive structures.

As evidenced by this literature review, the impact of trawling on SAV must be evaluated in light of the circumstances under which the fishery is prosecuted. These factors include gear type (size, weight, otter board weight, presence of tickler chain, presence of sweep; presence of rollers on sweep or footrope), gear usage (towing warp to water depth ratio), substrate composition, and SAV species.

Table 4. Fishing gears used in estuarine waters (E) for each Atlantic coast state, as provided by state marine fishery agency contacts (Appendix 1). Gears used in SAV are indicated by (S). Gear type names may differ among geographic regions, and are described in the report text.

GEAR TYPE		STATE											
		ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC	FL
Trawl	beam						E[1]	E, S[2]					E, S
	bottom, otter	E		E, S	E		E[1]					E	E
	Northern shrimp	E											
Dredge	bay scallop			E, S	E, S		E, S					E, S	
	sea scallop	E	E		E								
	urchin	E		E									
	mussel	E. S		E, S[3]									
	quahog	E[3]		E, S									
	crab						E	E	E		E	E	
	conch						E		E		E		
	oyster					E	E	E	E	E	E	E	
Dredge (hydraulic)	soft-shell			E						E, S			
	quahogs/surf clam			E, S	E	E				E, S			
Rake (other than oyster)	powered											E	
	hand	E, S	E	E, S	E, S	E, S	E, S	E	E, S			E, S	E
Tong	powered									E	E, S	E	
	hand	E	E	E, S	E, S	E, S	E, S	E	E, S	E	E	E, S	E
Sled	urchin		E										
Scrape	crab						E			E, S	E, S		
Clam Treading							E, S	E	E	E	E	E	E, S
Clam Kicking									E, S			E	
Pots, Traps	eel, crab, fish, conch, lobster or shrimp	E, S	E, S	E,S	E, S	E, S	E, S	E,S	E, S	E, S	E, S	E, S	E, S
Gill Net		E	E	E, S		E	E, S	E		E	E, S	E, S	
Rod & Reel		E, S	E, S	E, S	E, S	E, S	E, S	E, S	E, S	E, S	E, S	E, S	E
Pound Net							E, S			E	E, S	E, S	
Trotline	fish	E									E		
	crab						E, S			E, S	E, S		
Scuba		E, S		E, S		E, S	E, S			E			E
Weir	herring	E											
Seine	purse	E		E			E				E		
	haul			E, S		E	E, S	E, S	E, S	E, S	E, S	E, S	E

[1] very limited use of trawls (see Table 6)
[2] small (4 ft.) trawl used for shrimp
[3] use of these gears in estuaries or SAV has not been substantiated by marine fisheries agencies

Bay Scallop/Crab/Mussel/Oyster/Urchin Dredge – A dredge functions similarly to a trawl, in that it includes a net-like attachment that is dragged across the bottom to collect organisms. Dredges usually include a heavy metal frame less than 5 feet wide with a low rise that holds the net open. The frame includes a flat metal blade across the bottom, and may or may not include raking teeth on the blade (Sainsbury 1996).

Use of toothed dredges for bay scallops is frequently limited to sandy or gravelly bottom (Sainsbury 1996). Fonseca *et al.* (1984) found that toothless bay scallop dredging in *Zostera* beds grown in soft mud substrate resulted in a greater loss of vegetation biomass than dredging in beds grown in hard sand. Increased dredging measured by number of tows resulted in a significant reduction in vegetation biomass and number of shoots.

Blue crabs are harvested during winter months with dredges similar to bay scallop dredges. Dormant blue crabs burrow into sediments, and are raked into the dredge by the dredge's long teeth (10 cm). The dredges are pulled behind relatively small vessels (45,' DeAlteris 1998). Blue mussel dredges also contain teeth. In New York, crab dredges are also called crab "scrapes."

Hydraulic Clam Dredge – Hydraulic dredges use high pressure water jets to scour clams out of the sediment. Some estuarine gears include conveyor or escalator belt operations, immediately preceded by the water jets, to raise the scoured soft-shell clams to the surface (DeAlteris 1998). Offshore gear used in the surf clam and ocean quahog fisheries consists of a sled with jets on the anterior portion, followed by a blade that sieves the clams out of the sandy slurry and kicks them up into the posterior net (Sainsbury 1996).

When hydraulic clam dredging occurs in SAV beds, it digs up all vegetation in a swath approximately 3 feet wide (Stevenson and Confer 1978). Clam dredging has destroyed portions of SAV beds in both Maryland and Virginia estuaries (Orth 1999, Moore and Orth 1997). Fortunately, a comprehensive monitoring program provided evidence of these impacts, and a basis for regulations protecting certain areas (Orth 1999). Clam dredging can also significantly increase local turbidity (Ruffen 1995).

Clam Kicking – Clam kicking is a mechanical form of hard clam harvest practiced in North Carolina which involves the modification of boat engines so that the propeller wash is directed downwards instead of backwards (Guthrie and Lewis 1982). In shallow water, the propeller wash is powerful enough to suspend bottom sediments and clams (*Mercenaria mercenaria*) into a plume in the water column, which allows them to be collected in a trawl net towed behind the boat.

Clam kicking in North Carolina *Zostera/Halodule* beds was found to reduce SAV biomass (Peterson *et al*. 1987). Increased intensity of gear use resulted in increased loss of biomass and increased recovery time. Impacts from clam raking were similar to those from light intensity clam kicking.

Crab Scrapes – In the Chesapeake Bay's SAV beds, crab scraping is used to catch blue crabs which take cover there while shedding. Similar to bay scallop dredges, the scrapes consist of a rectangular metal frame with an attached baglike pocket of netting and a scraping bar across the bottom (Dumont and Sundstrom 1961). Observations of crab scraping in Chesapeake Bay suggest that the activity removes the upper parts of the leaves of SAV without critically disturbing roots and rhizomes (CBP 1995). A professional crab scraper will adjust the speed of his boat and the length of the tow warp to the depth of the water and the weight of the scrape in order to pull the scrape so it skims the bottom. It is counterproductive in crab scraping to either dig down into the sediment or drift up into the water column (Goldsborough, pers. com.). Therefore, this practice is considered to be sustainable for eelgrass dominated areas, because the shearing does not extend to its primarily below-ground meristematic tissue.

However, crab scraping is of concern for plants with above-ground meristems. In New York waters, the term "crab scrape" refers to the crab dredge described previously.

Haul Seine (beach) - A beach haul seine is a net of great length (hundreds of yards) and sufficient in height to run from the surface of the water column to the bottom. The floatline is suspended at the surface with floats and the leadline is weighted to ensure good contact with the bottom. Usually one end of the net is held on or nearshore, and the other end of the net is stretched so the width is fully extended. The moving end of the net is then pulled by either boat or net tender in an encircling path to the beach adjacent to the stationary end. Both ends are hauled at once (Sainsbury 1996). In North Carolina and Virginia, a small beach haul seine is called a "swipe" seine.

Sadzinski *et al*. (1996) found no detectable effects from haul seining on brackish SAV (*Vallisneria* and *Hydrilla)* plant height, plant density, or species composition in Chesapeake Bay. The extent of damage to SAV from haul seining is expected to be dependent upon seine length, weight and the density and height of the SAV habitat. Possible damage from haul seining to sexual reproduction such as flower shearing was not examined, but is expected to be similar to the results for leaf shearing, and therefore negligable (Naylor pers. com.).

Purse Seine – A purse seine is an encircling gear designed to catch species that run in schools near the surface of the water. The net is a long wall of webbing with a cork line and leadline. The net is deployed by encircling a school of fish with the wall of netting, and then cinching up the leadline to form a bottom pouch. The net does not touch the sea floor, so impacts to SAV are expected to be minimal.

Gill Net – An estuarine gill net is a stationary net made of monofilament that is kept open by anchors and buoys. Fish swim into the net, and are captured by entangling their fins or gills. Impacts to SAV are expected to be minimal.

Pound Net – A pound net is a fixed net with a long leader that guides fish into a pocket or "pound" which they cannot find their way out of. The net consists of an enclosure, with a leader extending out towards the shore. Pound nets are often kept in place for years on end. Impacts to SAV are expected to be minimal, unless the net is constructed directly in SAV.

Trotline – A trotline consists of a long horizontal main line to which baits are tied, either directly or to short lines know as "gangens" which are attached to the main line (Dumont and Sundstrom 1961). It is similar to a longline; however a trotline is more likely to be used in estuarine waters. Impacts to SAV are exptected to be minimal.

Rake - A bull rake consists of a long shaft with a rake and basket attached which are used to harvest clams. Usually the length and spacing of the teeth as well as the openings in the basket are regulated to protect juvenile clams from harvest (DeAlteris 1998). Mechanical bull rakes can be pulled along behind vessels.

Peterson et al. (1983) compared the impacts of two types of clam rakes on seagrass biomass. The bull rake removed over 80% of shoots, roots and rhizomes in a completely raked area while the pea digger removed 55% of shoots and 37% of roots and rhizomes.

Tongs – Hand tongs are a pair of rakes attached to the end of two long poles which are fastened together like a pair of scissors, with the fulcrum near the rake end (Dumont and Sundstrom 1961). A basket like frame is attached to the back side of each rake. The tongs are operated from a vessel, usually in less than twenty feet of water. Patent tongs are made of larger rakes with much shorter poles which are attached to a cable. Lifting the cable closes the tongs.

Scuba – Scuba gear is used either for collecting shellfish such as urchins or lobsters by hand, or for pursuing finfish with a spear or speargun. Impacts to SAV are expected to be minimal or non-existant.

Pots and Traps – Pots and traps are immobile gear that attract fish or crustaceans inside, usually by the use of bait. Once the fish, crab, or lobster enters the trap, it cannot find its way out. Although each individual trap has a relatively small footprint (approximately 4-8 square feet), the shear numbers of this gear could result in impacts of concern to SAV-habitat. The Florida Keys National Marine Sanctuary has concluded that derelict or long-soaking traps can displace seagrass (NOAA 1996). The Florida Division of Marine Resources estimated that at least 100,000 non buoyed "ghost" traps are located in state and Federal waters of the Florida Keys at any time during non-disaster years (Matthews 1999). A single storm in 1998 resulted in the loss of 118,000 lobster and stone crab traps in the Keys. Impacts from this fishery also result when gear is deployed in the fall and retrieved in spring because of increased vessel drafts when transporting gear (Kruer, pers. com.). Lobster traps in New England waters have been considered to contribute to SAV loss (Colarusso, pers. com.); however, scientific studies documenting these losses have not been completed.

Table 5. Fishing gear types used in state waters and their impacts to SAV, as determined by the Work Group. Gear use may be recreational or commercial in nature.

Gear Type	**Impact Type**				
	Above-Ground				**Below-Ground**
	Leaf shear	**Flower Shear**	**Turbidity**	**Burial**	
Clam kicking	x	x	x	x	**x**
Dredge – Hydraulic clam	x	x	x	x	**x**
Dredge – Bay scallop/mussel/etc. (toothed)	x	x	x	x	**x**
Dredge – Bay scallop (toothless)	x	x	x		**x**[1]
Scrape – Crab (toothless)	x	x	x		**x**[1]
Rake, hand or vessel operated	x	x	x	x	**x**
Tong, hand or vessel operated	x	x	x	x	**x**
Trawl	x	x	x		**x**[1]
Traps or pots	x	x		x	

Shore-side Fishing Related Impacts

Impacts to SAV can also occur from fishing related shore-side activities. Impacts associated with docks include shading, physical disturbance from boat hulls or propellers, and direct displacement (i.e. SAV replaced by structure). Under-regulated fish handling and processing facility discharge can contribute excess nutrients. Shading, direct displacement, and turbidity resulting from excess nutrient input can result from fish holding facilities. Repair yards can degrade local water quality through runoff containing toxic substances. Bulkheads can impact SAV by altering wave energy and causing wave reflection. Channel dredging causes direct displacement of SAV. Boat mooring areas can impact SAV by shading and increasing occurrences of prop scars (Short and Wyllie-Echeverria 1996). Excess chain on mooring buoys can drag over SAV causing continuous leaf shear and death of plants.

[1] Impacts of gear such as trawls, scrapes, and toothless dredges must be evaluated on an individual basis, considering the factors identified on p. 25, such as injury type, magnitude, and temporal extent, and susceptibility of the SAV species in question.

Shore-side activities can compete with SAV for available space. Because suitable habitat for SAV is limited by such factors as water quality, incident light, wave action and energy, as well as bottom type, it is difficult to find new suitable space for SAV to grow. Thus, an increase in shore-side activities near preferred SAV-habitat can result in loss or reduction of SAV. Further investigations similar to Burdick and Short (1999) regarding the impact of shore-side activities on SAV are needed, especially in light of cumulative effects on SAV. The guidelines presented in this report do not address shore-side impacts.

Aquaculture Impacts

Regulatory authority for aquaculture practices varies among states, and some aquaculture practices can adversely affect SAV (Short and Wyllie-Echeverria 1996, Goldsborough 1997, NOAA 1999). The work group identified the following impacts from shellfish culture rafts and finfish net pens: shading, direct displacement, current changes, increased nutrients/eutrophication, and, prevention of access by managed species if SAV beds are enclosed in net pens. Adverse effects can occur from transport of maintenance gear through SAV beds adjacent to shallow subtidal aquaculture plots. Harvest activity can also impact SAV through increased turbidity and gear impacts specific to aquaculture. The guidelines presented in this report do not address aquaculture practices and their impact to SAV in any further detail. Environmental impacts of aquaculture are addressed in detail in NOAA (1999).

DETERMINING IMPACTS OF SIGNIFICANT CONCERN

In order to proceed with determining the significance of an impact to SAV, we must first establish a context for the determination. For this report, significance of an impact will be based on the ASMFC's SAV policy goal, which calls for no net loss of SAV, and advocates an overall net gain. In this context, SAV is interpreted to mean "SAV-habitat" such as meadows or patchy areas described in the section *"Determining SAV Distribution."* Individual SAV plants would not be considered SAV-habitat. Based on this interpretation, the threshold for an impact of significance in this report will be the loss of SAV-habitat. Any impact that results in loss of SAV-habitat will be considered "an impact of significant concern." If an impact results in incidental loss or injury to an individual SAV plant, the impact would not be considered an impact of significant concern.

Many degrees of injury to SAV could impact SAV growth and/or reproduction, but would not be considered impacts of significant concern according to this threshold. Likewise, cumulative injuries could result in loss of SAV-habitat that might not be readily apparent. Unfortunately, the scientific information currently available is inadequate for a comprehensive evaluation of these issues.

Ideally, the degree of damage caused by a fishing gear impact to SAV should be evaluated using the following variables:

1) Type of injury;
2) Injury magnitude (calculated from frequency, intensity of application, and spatial extent of injury);
3) Susceptibility/recoverability of the species relative to injury and magnitude; and
4) Temporal extent of injury (i.e. short term loss of leaves via leaf shearing versus long-term loss of flowering parts)

Adequate information on the latter three factors is not available for most injuries. However, managers can use what little information is available regarding these factors to support risk-averse decision making. A few situations, such as below-ground impacts, clearly result in impacts to SAV of significant concern.

Below-Ground Impacts

Below-ground impacts to SAV (described on p. 17) such as crushing or chopping underground roots and growing tips result in lethal damage to SAV. Below-ground damage should always be considered an impact of significant concern because loss of SAV-habitat will occur. Thus, any impacts indicated by Table 5 to result in below-ground impacts are considered impacts of significant concern.

Above-Ground Impacts

Impacts to above-ground parts of SAV can be classified as impacts of significant concern if they result in loss of SAV-habitat. Loss of SAV habitat from above-ground impacts is especially evident for species of the genus *Halophila*. *Halophila spp.* have very short leaves and their above-ground growing tips are close to the sediment surface, and extremely susceptible to impacts to the sediment surface, such as those from bottom-tending mobile fishing gear. Therefore, both leaf shearing and below-ground disturbance should be considered impacts of significant concern for this species. Thus far, determination of impact significance for above-ground impacts to species other than *Halophila* is extremely difficult. Impacts from gear such as trawls, scrapes, and toothless dredges must be evaluated on a case-by-case basis, considering factors such as injury type, magnitude, and temporal extent, and susceptibility of the species in question. Although the factors to consider are clearly outlined above, thresholds for impact significance have not yet been determined.

Other Considerations and Cumulative Impacts

A methodology to quantify injury magnitude that may be useful in the future for determining gear impacts is being developed for use in natural resource damage assessments. Researchers at the National Ocean Service's (NOS) Beaufort Laboratory and at the National Oceanic and Atmospheric Administration's (NOAA) Damage Assessment Center have completed over four years of field research, and have developed a method to determine injury magnitude for SAV based on the area and shape of injury and percentage of resource impacted. A computer compensation model will use multiple parameters to account for differences in SAV species recovery ability. Research has focused on large-scale damage that resulted in 100% loss of ecological function of marine SAV species in the area of Florida Keys National Marine Sanctuary. Additional work may also be needed to determine if there are any injury thresholds for damage that results in less than 100% ecological function of the SAV.

This is one example of how injury magnitude can be quantified. However, this method requires baseline information on SAV distribution and shoot density, particularly during the peak of the growing season, to determine the area injured and resources lost. Obtaining SAV distribution data for each state would be the initial step for use of this approach. This information is currently not sufficiently detailed for all Atlantic coast states (Table 1).

When trying to determine the impact of fishing activity on SAV, consideration must be given to all possible impacts and ambient environmental quality. For example, dredging will not only affect any SAV that are buried, but may also affect nearby plants with increased turbidity. SAV plants can be stressed by fishing related shoreside activities, aquaculture, and/or other non-fishing related factors, including poor water quality, intense grazing (turtles or sea urchins), environmental change (salinity or temperature changes), and disease. Impacts on SAV from fishing activities could be magnified if plants are experiencing other stresses. Moreover, it is possible that stress from fishing activity could make SAV more susceptible to disease.

MITIGATION OF IMPACTS FROM FISHING ACTIVITIES

MITIGATION STRATEGIES

Mitigation is defined here as any activity employed to prevent loss of SAV or its habitat value. Mitigation strategies recommended in this report have been simplified from the five steps and sequencing outlined in the National Environmental and Policy Act (NEPA; P.L. 91-190 *et seq*). The four mitigation strategies identified for addressing fishing impacts to SAV are: (1) avoidance, (2) minimization, (3) restoration, and (4) creation. The benefits and liabilities of each of these mitigation strategies is further discussed below. Only avoidance and minimization were considered by the Work Group to have been consistently proven effective for conservation of SAV.

Avoidance

The objective of the avoidance strategy is to prevent or "avoid" any impact to SAV from fishing gear. Use of this strategy is indicated when SAV is particularly vulnerable (e.g. *Halophila*), fishing gear particularly damaging, or information dearth warrants a risk-averse approach. Possible avoidance actions include year round closures of SAV beds to fishing activities or prohibition of certain gear use in SAV beds.

Year Round Closures to All Gear - Year round closures provide the greatest protection to SAV since the total area of concern can be protected to the greatest extent possible. In addition to the benefits of an SAV bed, protected areas of SAV can also provide a source for future SAV expansion. Liabilities associated with year round closures can include shifted fishing effort to other sensitive habitats. Furthermore, closures may inhibit the spread of SAV along the bed borders, since fishing activity often occurs right up to the edges of the closed area. This type of closure is not currently in effect in any Atlantic coast state.

Gear prohibitions - Prohibition of the use of specific gears in SAV has been one of the most widely and successfully implemented mitigation strategies. The states of Virginia, North Carolina, Massachusetts, and Maryland have all implemented regulations that provide protection to SAV by prohibiting the use of gears such as mechanical bullrakes and hydraulic clam dredges in SAV beds (Table 6). Some of the same liabilities associated with year round closures are also associated with gear prohibitions. In addition, fishermen may compensate by increasing effort with unrestricted gear in the same area, which may cause damage from the increased magnitude of impact.

Minimization

The objective of the minimization strategy is to limit or minimize adverse impacts to SAV from fishing. Specific examples of this strategy include partial area closures (rotational, seasonal, tidal), and gear modifications. When feasible, incentive-based activities such as providing for the use of habitat-friendly gear are preferred, since incentive based activities are more likely to be accepted and adhered to by harvesters, and thus more effective.

Partial Area Closures - Partial area closures include the closure of areas to fishing activity on some limited time scale. Closures could be on a rotating basis (e.g., every other year), for a specific period of time such as SAV growing or reproductive seasons or during part of the tidal cycle.

The purpose of a rotational closure is to allow a recovery period for SAV within the closure area. For example, access for certain gear types could be rotated on an annual basis—shrimping in odd-numbered years, seining in even-numbered years, or both in the same year but nothing in the next. The time period for an effective recovery period will vary depending upon the injury and species of SAV involved. For most gears, this type of data is not available. As with most other strategies, fishing effort may be displaced to other areas, and could increase adverse impacts to SAV outside the regulated area.

Table 6. Summary of state fishing gear regulations implemented to protect SAV or implemented for fisheries management purposes, with the indirect benefit of protecting SAV, as provided by state marine fisheries agency contacts.

State	Fishing Gear Regulation	Regulation Intent	
		Habitat Protection	Fisheries Management
ME	Time and area restrictions for the use of various gears throught state waters	x	x
NH	Restriction of mobile gear in state waters; (exemptions only occur in non-estuarine waters during winter)	x	x
MA	Trawls and sea scallop dredges are seasonally prohibited in limited areas of south shore of Cape Cod to protect *Zostera*	x	x
RI	No dredging for scallops in specific coastal ponds and rivers from December 31-November 15	x	x
	No dredging for shellfish in RI waters unless otherwise specified; no dredging in specific coastal ponds and rivers		x
	Trawling limited by area and season in RI waters		x
CT	Bay scallop dredging prohibited in un-leased bottom	x	x
	Inshore trawling prohibited (no-trawling areas include river mouths, harbors and embayments) in Long Island Sound		x
NY	Trawl closure areas in many estuaries, including western Long Island Sound and inlets		x
NJ	Gill nets*, mechanical clam dredges*, and otter trawls prohibited in coastal bays *(excluding Delaware Bay which has no SAV)		x
DE	No trawling or hydraulic dredging in state waters		x
MD	Crab scrapes must be toothless; restrictions on scrape size, weight, use, and number per boat	x	
	Hydraulic clam dredge prohibited in SAV; SAV is delineated via maps based on annual aerial surveys	x	
	Trawling prohibited in state waters		x
	Haul seine gear restricted by length		x
VA	Coastal bay closure to clam harvest in mapped SAV & 200' buffer	x	
	Clam dredging prohibited in waters <4' deep		x
	SAV designated as sanctuaries in seaside Eastern Shore where clamming and dredging are prohibited	x	
NC	Mechanical shellfishing and bullraking prohibited in SAV	x	
	Shrimp and crab trawling prohibited in primary nursery areas	x	x
	Bay scallop dredges must be toothless and are weight restricted. Areas where gear can be used are limited by proclamation of the Director of NC Division of Marine Fisheries	x	
FL	Commercial netting is banned in state waters	x	x
	Reef areas have mooring points and some limit recreational and commercial fishing	x	
	Near shore and inshore areas closed to shrimp trawls (delineated via maps)	x	x
	Clearly marked navigation channels	x	
	Areas of no internal combustion engines	x	
	Shellfishing (except for treading) in Indian River Lagoon seagrass is prohibited	x	

Seasonal closures can protect critical life history stages, namely growing and/or reproductive periods. For example, closing an area for the specific time period associated with SAV flowering would minimize gear impacts at a critical period, allowing the sexual reproductive cycle to occur unimpeded.

During non-flowering times, SAV could incur some damage, such as leaf shearing, without affecting its sexual reproductive cycle. Since SAV species grow and reproduce at different times, seasonal closures must be tailored to the specific vulnerable season for each species under consideration. Effort displacement during the closure could be a liability, and any injury which occurs during the open season that affects asexual reproduction/growth should be evaluated.

Tidal closure programs are an option for protecting SAV beds from propeller scarring during low tides, when beds are most susceptible to this type of impact. SAV beds can be marked with poles painted two colors, for example – half green and half red. At high tide, only the green portion of the pole shows, indicating it is safe to boat over the SAV bed. At low tide, part of the red portion of the pole is exposed, indicating that the area should be avoided. This approach would apply to both fishing and non-fishing vessels alike.

Gear Format Restrictions or Modifications - Restricting gear size or format provides another means of protecting SAV. A number of states have implemented regulations requiring gear modifications that reduce impacts to SAV. In North Carolina, bay scallop dredges must be toothless and below a certain weight restriction in order to minimize injury to SAV. Crab scrapes in Maryland must also be toothless to protect SAV. Some shrimp trawl fishermen in North Carolina are voluntarily putting PVC pipe over tickler chains which decreases drag and protects SAV (P. Murphey, pers. com.). An important consideration for gear modification is that if the frequency of the gear use increases, it could offset the reduction in damage gained from the modification.

Restoration and Creation

Restoration can be defined as a return to a previously existing natural, or altered condition (Lewis 1989). Attempts to restore/create SAV beds have not been very successful (Lewis 1997, Fonseca pers. observation). Methodology for planting techniques are well-documented (Fonseca *et al*. 1998, Fonseca 1994, Fonseca 1992); however, lack of adequately trained personnel has impacted efficacy of restoration projects. Moreover, environmental conditions including water quality must be favorable for SAV growth and reproduction, otherwise establishment of SAV will likely fail. Although it is possible to restore SAV, preservation is the most cost-effective option for sustaining these resources (Fonseca *et al*. 1998).

In addition to the costs involved in restoration and creation, other hardships include identifying a suitable location, and selecting and applying suitable planting techniques. Finding a suitable site is often the most limiting factor in creating SAV. In fact, when SAV in an area is lost, the subsequent loss of sediment stability and increased turbidity can reduce the suitability of that particular area for SAV restoration (Fonseca *et al*. 1998). Although the NOAA Coastal Ocean Program's recently published *Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters* (Fonseca *et al.* 1998) has substantially organized and improved the knowledge base available on SAV restoration and creation, even this document supports the primary use of impact avoidance and minimization as the best mitigation strategy. In general, it is believed that resource managers have become educated about the value of SAV resources and repair costs, and routinely emphasize impact avoidance and minimization over restoration or creation (CBP 1995, Fonseca *et al*. 1998). Protection of areas with documented or historical SAV along with transplanting/seeding to enhance recovery of previously impacted areas offer the most likely chance of success for conservation of SAV-habitat.

For purposes of this document, restoration and creation of SAV will not be considered a suitable strategy for mitigating impacts from fishing gear. For states with a well-established SAV restoration program that has been documented to be successful, this determination could be reconsidered. However, success is often contingent upon identification of a responsible party and recovering penalties to pay for the planting, which may not be possible for many gear impacts.

GUIDELINES FOR USING MITIGATION STRATEGIES

The previous sections of this report served to outline the necessary basis for understanding the potential impacts of fishing gear on submerged aquatic vegetation, and identified mitigation strategies for these impacts. This final report section will describe guidelines for applying the mitigation strategies identified, based on the postulates and conclusions that were derived in earlier sections. The manager applying these guidelines is encouraged to keep two things in mind: 1) the ecological importance of SAV warrants application of a risk-averse approach to management; and 2) a number of considerations – namely, economic impacts and enforceability of actions – have not yet been integrated. Further guidance on these issues will either be integrated at a later date, or addressed in a separate document. Finally, federal regulation of impacts to the threatened *H. johnsonii* have not yet been established[5], but should be incorporated in these guidelines upon promulgation.

A decision tree which incorporates a systematic review of potential impacts and suggested mitigation strategies is given in Figure 2. As previously stated, the Commission's goal of "no net loss" of SAV was used to establish this report's baseline of plant loss or death as a "significant impact" to SAV. Significant impacts have been shown to result unequivocally from below-ground impacts to most SAV species, and above-ground disturbance for *Halophila* spp. Fishing gear that result in below-ground disturbances are identified in Table 5. This type of impact should be avoided at most, if not all costs, and mitigation activities listed under the "Avoidance" strategy should be applied (Figure 2).

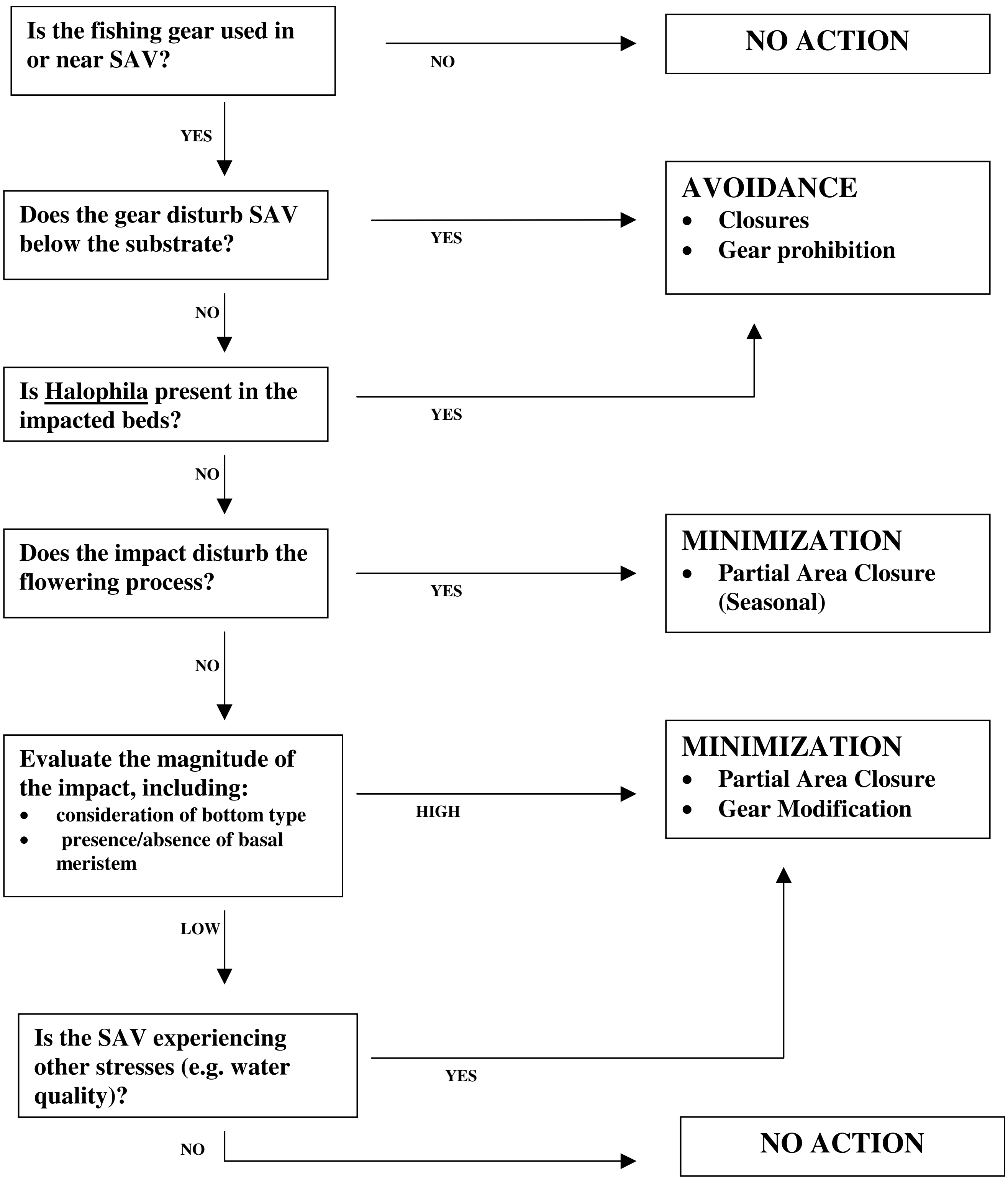
Disturbance to sexual reproduction is the impact of next greatest concern. Impacts that interfere with flowering or seed setting can affect the amount of SAV present in the upcoming year. In most cases, partial area closures should be used to offset any seasonal impacts of concern. More risk-averse actions, such as full area closures, may also be used.

Impacts which do not fit into the three categories of impacts described above must be evaluated for degree of impact. As stated earlier in the report, the degree of impact determination is subjective since so little scientific research has occurred in this discipline. Factors which should be considered in this evaluation are described in the section of the report entitled "*Determining Impacts of Significant Concern.*" If the degree of impact to SAV is considered to be high, then minimization strategies should be employed. If the degree of impact is low, then other environmental stresses should be taken into account when evaluating the need for mitigation. For example, if ambient water clarity is low or borderline for SAV health, a more risk averse approach should be taken in the application of mitigation strategies, and minimization should be pursued. If there is little additional stress, then no action is required.

If the information available is insufficient to apply the guidance outlined above and in Figure 2, then the most risk-averse mitigation strategy of "Avoidance" should be implemented.

[5] Protection of endangered or threatened species and their habitat is governed by the Endangered Species Act (P.L. 93-205 *et seq.*). Conservation measures for the protection of *Halophila johnsonni* will be determined in the near future (63 F.R. 19035).

Figure 2. Decision tree for identifying appropriate mitigation strategies for fishing gear impacts to SAV. When information is insufficient for use of this tree, the most risk-averse mitigation strategy of *Avoidance* should be implemented.



ADDITIONAL RECOMMENDATIONS AND RESEARCH NEEDS

Education on protecting SAV is needed for fishermen and the recreational boating community. Some measures are being implemented to improve channel markings so boats will stay in the navigation channels and away from SAV beds. Further advancement in this area is needed.

Although outside the scope of this report, the Work Group strongly encourages the Commission to address impacts from all watercraft (both fishing and non-fishing boats, jet skis etc.) including such factors as physical damage to SAV as well as pollution and disturbance to wildlife.

The following research needs apply specifically to the issue of gear impacts:

- Mapping and monitoring of SAV on a regular basis is essential for determining distribution, loss and recovery of SAV. This information is especially important with regard to implementing and monitoring effectiveness of mitigation actions. Aerial photography is an effective means of mapping and monitoring SAV. Geographic Information Systems (GIS) capability permits mapping of fishing grounds and SAV distribution to identify where the two areas overlap, and to identify changes in beds overtime. Actions can be focused on the identified areas for effective mitigation.

- Research is needed to determine the injury and recovery potential of SAV species to different magnitudes of gear impacts. In addition, information is needed on the frequency of use of the different gear types.

- Although, generally, the impact to SAV from physical damage is considered small when compared to water quality impacts, more research is needed to determine whether or not physical damage to SAV can cause large-scale losses. In particular Burdick and Short (1999) have posed the question as to whether or not fragmentation of habitat can initiate a large-scale decline.

- Research is needed to identify the use/value of SAV beds (marine, tidal, and freshwater). Comprehensive surveys are also needed on the use of beds by other organisms (e.g., mammals, fish, birds, invertebrates) and possible impacts from various human activities such as fishing boat activities, sand and gravel mining, turbidity impacts, and secondary-treated wastewater discharges. Such information is particularly lacking for tidal and freshwater SAV beds.

- An assessment of the impact of shore-side activities on SAV is needed, especially in light of their possible relationship (cumulative/synergistic) to other impacts to SAV from fishing activities.

REFERENCES

Ardizzone, G.D. and P. Pelusi. 1983. Fish populations exposed to coastal bottom trawling along the Middle Tyrrhenian Sea. Rapp. Roc. Verb. Reun. CIESM. Vol. 28(5): 107-110.

Ardizzone, G.D., P. Tucci, A. Somaschini, and A. Belluscio. 2000. Is bottom trawling partly responsible for the regression of *Posidonia oceanica* meadows in the Mediterranean Sea?, pp. 37-46 *in* M.J. Kaiser and S.J. de Groot, eds., The Effects of Fishing on Non-target Species and Habitats: Biological, Conservation and Socio-economic Issues. Blackwell Science.

ASMFC. 1997. Submerged Aquatic Vegetation Policy. ASMFC Habitat Management Series No. 3. Washington, DC. 9 p.

Auster, P.J. and R.W. Langton. 1999. The effects of fishing on fish habitat, pp. 150-187 *in* L. Benaka, editor, Fish Habitat: Essential Fish Habitat and Rehabilitation. American Fisheries Society, Symposium 22. Bethesda, MD.

Barnette, M.C. 1999. Gulf of Mexico Fishing Gear and their Potential Impacts on Essential Fish Habitat. NOAA Tech. Mem. NMFS-SEFSC-432. St. Petersburg, FL. 24 p.

Batiuk, R., P. Bergstrom, M. Kemp, E. Koch, L. Murray., C. Stevenson, R. Bartleson, V. Carter, N. Rybicki, J. Landwehr, C. Gallegos, L. Karrh, M. Naylor, D. Wilcox, K. Moore, and S. Ailstock. In Press. Chesapeake Bay Submerged Aquatic Vegetation Water Quality and Habitat-based Requirements and Restoration Targets: a Second Technical Synthesis. Environmental Protection Agency (EPA) Chesapeake Bay Program, Annapolis, MD.

Batiuk, R.A., R.J. Orth, K.A. Moore, W.C. Dennison, J.C. Stevenson, L.W. Staver, V. Carter, N.B. Rybicki, R.E. Hickman, S. Kollar, S. Bieber, and P. Heasly. 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: a Technical Synthesis. Chesapeake Bay Program, EPA, Annapolis, MD. CBP/TRS 83/92. 186 p.

Berkeley, S.A., D.W. Pybas, and W.L. Campos. 1985. Bait Shrimp Fishery of Biscayne Bay. Florida Sea Grant College Program Technical Paper No. 40. University of Florida, Gainesville, FL.

Bridger, J.P. 1972. Some Observations on Penetration into the Sea Bed of Tickler Chains on a Beam Trawl. ICES CM 1972/B:7. Gear and Behavior Committee. 9 p.

Brylinsky, M., J. Gibson, and D.C. Gordon, Jr. 1994. Impacts of flounder trawls on the intertidal habitat and community of the Minas Basin, Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences. Vol. 51: 650-661.

Burdick, D.M. and F.T. Short. 1999. The effects of boat docks on eelgrass beds in the coastal waters of Massachusetts. Environmental Management 23(2): 231-240.

Camp, D.K., S.P. Cobb, and J.F. Van Breedveld. 1973. Overgrazing of seagrass by a regular urchin *Lytechinus variegatus*. Bioscience 23: 37-38.

Carraway, R.J. and L.J. Priddy. 1983. Mapping of Submerged Grass Beds in Core and Bogue Sounds, Carteret County, North Carolina, by Conventional Aerial Photography. North Carolina Coastal Energy Impact Program. Location Report No. 20. 86 p.

Carter, Virginia. U.S. Geological Survey, retired, Wakefield, RI. Phone: 401/783-3854.

Carter, V. and N.B. Rybicki. 1985. The effects of grazers and light penetration on the survival of transplants of *Vallisneria americana* in the tidal Potomac River, Maryland. Aquat. Bot. 23: 197-213.

CBP (Chesapeake Bay Program). 1995. Guidance for Protecting Submerged Aquatic Vegetation in Chesapeake Bay from Physical Disruption. EPA, Annapolis, MD. 11 p. plus appendices.

Colarusso, Phil. Environmental Protection Agency, Boston, MA. Phone: 617/918-1620.

DeAlteris, J. 1998. Training Manual Fisheries Science and Technology; Prepared for the NOAA Corps Officer Program. 34 p.

DeAlteris, J., L. Skrobe and C. Lipsky. 1999. The significance of seabed disturbance by mobile fishing gear relative to natural processes: a case study in Narragansett Bay, Rhode Island, pp. 224-237 *in* L. Benaka, ed., Fish Habitat: Essential Fish Habitat and Rehabilitation. American Fisheries Society, Symposium 22, Bethesda, MD.

de Groot, S.J. 1984. The impact of bottom trawling on benthic fauna of the North Sea. Ocean Management. Vol. 9: 177-190.

Dobson, J.E., E.A. Bright, R.L. Ferguson, D.W. Field, L.L. Wood, K.D. Haddad, H. Iredale, J.R. Jensen, V.V. Klemas, R.J. Orth, J.P. Thomas. 1995. NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation. NOAA Technical Report NMFS 123, 92 p.

Drew, S.C. and R.E. Larsen. 1994. Worldwide Trawl and Dredge Study. Marine Data Systems. Plymouth, MA. 8 p.

Dumont, W.H. and G.T. Sundstrom. 1961. Commercial Fishing Gear of the United States. U.S. Fish and Wildlife Service Fish and Wildlife Circular 109. Washington, DC. 61 p.

Ernst, L.M. and C. D. Stephan. 1997. State regulation and management of submerged aquatic vegetation along the Atlantic Coast of the United States, pp. 40-56 *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.

Fonseca, M.S. 1998. Exploring the Basis of Pattern Expression in Seagrass Landscapes. Ph.D. Dissertation, Department of Integrative Biology, University of California, Berkeley, CA. 222 p.

Fonseca, M.S. 1994. A Guide to Planting Seagrasses in the Gulf of Mexico. Texas A&M University Sea Grant College Program. TAMU-SG-94-601. 27 p.

Fonseca, M.S. 1992. Restoring seagrass systems in the United States, pp. 79-110 *in* G.W. Thayer (ed.), Restoring the Nation's Marine Environment. Maryland Sea Grant College, College Park, Maryland.

Fonseca, M.S. 1989. Regional analysis of the creation and restoration of seagrass systems, pp. 175-198 *in* J.A. Kusler and M.E. Kentula (eds.), Wetland Creation and Restoration: the Status of the Science. Vol.1: Regional Reviews. U.S. EPA Environmental Research Lab., Corvallis, Oregon. EPA/600/3-89/038a.

Fonseca, M.S. and S.S. Bell. 1998. Influence of physical setting on seagrass landscapes near Beaufort, North Carolina, U.S.A. Marine Ecology Progress Series 171: 109-121.

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 p.

Fonseca, M.S., G.W. Thayer, A.J. Chester, and C. Foltz. 1984. Impact of scallop harvesting on eelgrass (*Zostera marina*) meadows: implications for management. North American Journal of Fisheries Management 4:286-293.

Fonseca, M.S., P.E. Whitfield, N.M. Kelly, S.S. Bell. *In Review*. Statistical modeling of seagrass landscape pattern and associated ecological attributes in relation to hydrodynamic gradients. Ecol. Applications.

Goldsborough, William J. Chesapeake Bay Foundation, Annapolis, MD. Phone: 410/268-8816.

Goldsborough, W.J. 1997. Human impacts on SAV – A Chesapeake Bay case study, pp. 36-39 *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.

Greenway, M. 1974. The effects of cropping on the growth of *Thalassia testudinum* (Koenig) in Jamaica. Aquaculture 4: 199-206.

Guillen, J.E., A.A. Ramos, L. Martinez, and J.L. Sanchez-Lizaso. 1994. Antitrawling reefs and the protection of *Posidonia oceanica* (L.) Delile Meadows in the western Mediterranean Sea: demand and aims. Bulletin of Marine Science. Vol. 55(2): 645-650.

Guthrie, J.F. and C.W. Lewis. 1982. The clam-kicking fishery of North Carolina. Marine Fisheries Review 44(1): 16-21.

Hurley, L.M. 1991. Submerged aquatic vegetation, pp. 2-1 – 2-19 *in* Chesapeake Bay Program, Habitat Requirements for Chesapeake Bay Living Resources. Annapolis, MD.

Kantrud, H.A. 1990. Sago pondweed (*Potamogeton pectinatus* L.): A literature review. U.S. Fish and Wildlife Service, Fish and Wildlife Research Publication 176. Jamestown, ND.

Kantrud, H.A. 1991. Wigeongrass (*Ruppia maritima* L.): A literature review. U.S. Fish and Wildlife Service, Fish and Wildlife Research Publication 810. Jamestown, ND. 58 p.

Kenworthy, W.J. and D.E. Haunert. 1991. The Light Requirements of Seagrasses: Proceedings of a Workshop to Examine the Capability of Water Quality Criteria, Standards and Monitoring Programs to Protect Seagrasses. National Oceanic and Atmospheric Administration Tech. Memo. NMFS-SEFC-287. Beaufort, N.C. 181 p.

Kraemer, G.P., R.H. Chamberlain, P.H. Doering, A.D. Steinman, and M.D. Hanisak. 1999. Physiological responses of transplants of the freshwater angiosperm *Vallisneria americana* along a salinity gradient in the Caloosahatchee estuary (southwestern Florida). Estuaries 22(1): 138.

Kruer, Curtis. P.O. Box 753, Sheridan, MT. Phone: 406/842-5052.

Laney, R.W. 1997. The relationship of submerged aquatic vegetation (SAV) ecological value to species managed by the Atlantic States Marine Fisheries Commission (ASMFC): summary for the ASMFC SAV Subcommittee, pp. 11-35 *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.

Lewis, R.R. 1997. Restoration or enhancement projects to benefit fisheries: seagrasses, pp 88-91 *in* Stephan, C.D. and K. Beidler, editors, Management of Atlantic Coastal Marine Fish Habitat: Proceedings of a Workshop for Habitat Managers. ASMFC Habitat Management Series No. 2.

Lewis, R.R. 1989. Wetlands restoration/creation/enhancement terminology: suggestions for standardization, pp. 1-8 *in*: Kusler, J.A. and M.E. Kentula (eds.). Wetland Creation and Restoration: The Status of the Science. Vol. II Perspectives. Environ. Res. Lab., Corvallis, OR. EPA/600/3-89/038b.

MAFMC and ASMFC. 1998. Amendment 12 to the Summer Flounder, Scup and Black Sea Bass Fishery Management Plan. Mid-Atlantic Fishery Management Council, Dover, DE. 398 p. plus appendices.

Matthews, Tom. 1999. Presidential Task Force Report. Florida Department of Environmental Protection. Marathon, FL, 1 p.

Meyer, D.L., M.S. Fonseca, P.L. Murphey, R.H. McMichael, Jr., M.M. Byerly, M.W. Lacroix, P.E. Whitfield, and G.W. Thayer. 1999. Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, FL. Fishery Bulletin 97(1): 193-199.

Moore, K.A. and R.J. Orth. 1997. Report to the Virginia Marine Resources Commission: Evidence of Widespread Destruction of Submersed Aquatic Vegetation (SAV) from Clam Dredging in Chincoteague Bay, Virginia. 3 p.

Murphey, Patricia. North Carolina Division of Marine Fisheries, Morehead City, NC. Phone: 252/726-7021.

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. Marine Ecology Progress Series, 121:91-98.

Naylor, Mike. MD Department of Natural Resources, Annapolis, MD. Phone: 410/260-8652.

NEFMC (New England Fishery Management Council). 1998. Amendment #11 to the Northeast Multispecies Fishery Management Plan (FMP), Amendment #9 to the Atlantic Sea Scallop FMP, Amendment #1 to the Monkfish FMP, Amendment #1 to the Atlantic salmon FMP, and Components of the Proposed Atlantic Herring FMP for Essential Fish Habitat. NEFMC, Saugus, MA. 388 p. plus appendices.

NOAA (National Oceanic and Atmospheric Administration). 1999. The Environmental Impacts of Aquaculture. National Ocean Service, Marine Sanctuaries Division and National Marine Fisheries Service, Northeast Region, Office of Habitat Conservation. Silver Spring, MD. 31 p.

NOAA. 1996. Florida Keys National Marine Sanctuary Final Management Plan and Environmental Impact Statement. 3 Volumes. NOAA/NOS/OCRM/Sanctuaries and Reserves Division. Marathon, FL.

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 p. plus appendices.

Orth, Robert. Virginia Institute of Marine Sciences, Gloucester Point, VA. Phone: 804/684-7000.

Orth, R.J. 1999. Letter to Maryland Department of Natural Resources Secretary Griffen Concerning Dredge Scars in Maryland Coastal Bay SAV Beds. 2 p.

Peterson, C.H., H.C. Summerson, and S.R. Fegley. 1987. Ecological consequences of mechanical harvesting of clams. Fishery Bulletin 85(2): 281-298.

Peterson, C.H., H.C. Summerson, and S.R. Fegley. 1983. Relative efficiency of two clam rakes and their contrasting impacts on seagrass biomass. Fishery Bulletin. 81(2): 429-434.

Raven, P.H., R.F. Evert and H. Curtis. 1976. Biology of Plants. Worth Publishers, New York, NY. 685 p.

Ruffen, K. 1995. Effects of hydraulic clam dredging on nearshore turbidity and light attenuation in Chesapeake Bay, Maryland. MS Thesis, University of Maryland. 97 p.

Sadzinski, R., M. Naylor, D. Weinrich, J.H. Uphoff Jr., H. Speir and D. Goshorn. 1996. Effects of Haul Seining on Submerged Aquatic Vegetation in Upper Chesapeake Bay. Maryland Department of Natural Resources (DNR) Fisheries Service, Fisheries Technical Report No. 20, Maryland DNR, Annapolis, MD. 40 p.

SAFMC (South Atlantic Fishery Management Council). 1998. Habitat Plan for the South Atlantic Region: Essential Fish Habitat Requirements for Fishery Management Plans of the South Atlantic Fishery Management Council. SAFMC, Charleston, SC. 457 p. plus appendices.

Sainsbury, J.C. 1996. Commercial Fishing Methods, an Introduction to Vessels and Gear. Third Edition. Fishing News Books. Osney Mead, Oxford, England. 360 p.

Sargent, F.J., T.J. Leary, D.W. Crewz and C.R. Kruer. 1995. Scarring of Florida's Seagrasses: Assessment and Management Options. FMRI Tech. Rep. TR-1. Florida Marine Research Institute, St. Petersburg, Florida. 37 p. plus appendices.

Short, F.T. and S. Wyllie-Echeverria. 1996. Natural and human-induced disturbances of seagrasses. Environ. Cons. 23(1): 17-27.

Smith, E., M.A. Alexander, M.M. Blake, L. Gunn, P.T. Howell, M.W. Johnson, R.E. MacLeod, R.F. Sampson, D.G. Simpson, W.H. Webb, L.L. Stewart, P.J. Auster, N.K. Bender, K. Buchholz, J. Crawford, and T.J. Visel. 1985. A Study of Lobster Fisheries in the Connecticut Waters of Long Island Sound with Special Reference to the Effects of Trawling on Lobsters. Unpublished Report. CT Department of Environmental Protection, Marine Fisheries Program. Hartford, CT.

Stephan, C.D. and T.E. Bigford (eds.). 1997. 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. 78 p.

Stevenson, J.C. and N.M. Confer. 1978. Summary of Available Information on Chesapeake Bay Submerged Vegetation. U.S. Fish and Wildlife Service Office of Biological Services. FWS/OBS-78/66. 335 p.

Thayer, G.W., W.J. Kenworthy, and M.S. Fonseca 1984. The Ecology of Eelgrass Meadows of the Atlantic Coast: A Community Profile. U.S. Fish & Wildlife Service. FWS/OBS-84/02. 147 p.

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..

Tiner, R.W. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. University of MA Press, Amherst, MA. 285 p.

Townsend, E.C. and M.S. Fonseca. 1998. Bioturbation as a potential mechanism influencing spatial heterogeneity of North Carolina seagrass beds. Marine Ecology Progress Series 169:123-132.

U.S. Geological Survey. 1997. American wildcelery (*Vallisneria americana*): ecological considerations for restoration. Northern Prairie Wildlife Research Center Homepage. http://npwrc.usgs.gov/resource/literatr/wildcel/intro.htm

Valentine, J.F. and K.L. Heck. 1991. The role of sea urchin grazing in regulating subtropical seagrass meadows: evidence from field manipulations in the northern Gulf of Mexico. J. Exp. Mar. Bio. Ecol. 154:215-230.

Valentine, J.F., K.L. Heck, P. Harper, and M. Beck. 1994. Effects of bioturbation in controlling turtlegrass (*Thalassia testudinum* Banks ex Konig) abundance: evidence from field enclosures and observations in the northern Gulf of Mexico. J. Exp. Mar. Biol. Ecol. 178:181-192.

Zieman, J.C. 1976. The ecological effects of physical damage from motor boats on turtlegrass beds in southern Florida. Aquat. Bot. 2:127-139.

APPENDIX 1

STATE MARINE FISHERIES AGENCY CONTACTS

Maine
Mercer, Linda
Maine Department of Marine Resources
P.O. Box 8
W. Boothbay Harbor, ME 04575
207/633-9500

New Hampshire
Nelson, John and Douglas Grout
New Hampshire Fish and Game
37 Concord Road
Durham, NH 03824
603/898-1095

Massachusetts
Caruso, Paul
Massachusetts Division of Marine Fisheries
50 A Portside Drive
Pocasset, MA 02559
08/563-1779 x-107

Rhode Island
Powell, Chris
Rhode Island Division of Fish and Wildlife
150 Fowler Street, Wickford, RI 02852
401/294-9640

Connecticut
Simpson, Dave
Connecticut Marine Fisheries
P.O. Box 719
Old Lyme, CT 06371
860/434-6043

New York
Young, Byron and Art Newell
New York Department of Environmental Conservation
205 Belle Meade Road
East Setauket, New York 11733
516/444-0435

New Jersey
Halgren, Bruce
New Jersey Division of Fish and Wildlife
CN 400, 501 East State Street, Trenton, NJ 08625
609/292-2083

Delaware
Lesser, Charlie
Delaware Division of Fish and Wildlife
89 Kings Highway
Dover, DE 19901
302/739-3441

Maryland
Speir, Harley
Maryland Department of Natural Resources
Tawes Building, 580 Tower Avenue
Annapolis, MD 21401
410/260-8303

Virginia
O'Reilly, Rob
Virginia Marine Resources Commission
P.O. Box 756
Newport News, VA 23607-0756
757/247-2236

North Carolina
Street, Mike
North Carolina Division of Marine Fisheries
P.O. Box 769
Morehead City, NC 28557
252/726-7021

Florida
Kennedy, Stu
Florida Fish and Wildlife Conservation Commission
100 Eighth Avenue, SE, J4-FA
St. Petersburg, FL 33701-5095
727/896-8626