Title: SHALLOW WATER RESOURCE USE CONFLICTS: CLAM AQUACULTURE AND SUBMERGED AQUATIC VEGETATION

Authors: C. Hershner and H. Woods

Center for Coastal Resources Management,
Virginia Institute of Marine Science, Rt. 1208 Greate Rd., Gloucester Pt. VA 23062, carl@vims.edu

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Application Tool: GIS (ArcInfo 7.2); Remote Sensing (aerial photos for SAV inventory).

Main Issues Addressed: Management of aquaculture together with fisheries.

The general problem, or aim of the study, and the contribution of GIS, remote sensing and/or mapping to the solving the problem: This project was designed to assess the potential conflict of subaqueous bottom land use by SAV and hard clam aquaculture in a region of current intensive aquaculture. The goal was to provide background data for discussion of management issues, using available data and GIS tools and models. The project was not designed to provide a definitive resolution. The intention was rather to document the current situation, develop and test an analytical approach, and identify several options for further policy debate. It is envisioned that there will be continuing work on this issue, with additional efforts to refine the background data, analytical tools (integrated GIS modelling analysis), as well as policy options. Development and application of some simple habitat/use suitability models to assess the potential conflict are included. We identified several policy/management options, suggested by assessment of the study area, and provide suggestions for future iterations of this type of study.

Main Environments: Brackishwater.

Culture Systems: On bottom.

Organism Divisions: Molluscs.

Genera and Species: Hard clam, (*Mercenaria mercenaria*).

Target Country: Virginia, USA.

Target Audience: Coastal managers, aquaculture planners, integrated ecosystem managers.

Duration of the Study and Year Begun: two years, from 1997.

Personnel Involved: Marine scientist and coastal resources manager who conceived and coordinated the study, and was the principal author of report; Marine scientists collected and prepared data for analyses; A GIS analyst provided assistance in data acquisition and interpretation (VIMS Submerged Aquatic Vegetation Inventory Program); GIS Analysts and a modeller provided data interpretation and GIS analyses, and generated resulting maps.

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Introduction

Hard clam (*Mercenaria mercenaria*) aquaculture is a growing and thriving industry in the Commonwealth of Virginia. In 1997 alone, it was worth nearly $10 millions (Virginia Agricultural Statistics Service, 1998). This and other aquaculture industries are promoted by the Commonwealth as a sustainable fishery with important economic ramifications for the citizens of the Commonwealth (Virginia Department of Agriculture and Consumer Services, 1995; Thacker, 1994). As such, aquaculturists are permitted to benefit at minimal cost from a variety of public resources including public bottom land and the public water column.

Submerged aquatic vegetation (SAV) (*Zostera marina* and *Ruppia maritima*) in the Chesapeake Bay is an important habitat for fish and blue crabs (Heck and Thoman, 1984; Pardieck, 1996; Schulman *et al*., 1996) as well as a food source for waterfowl (Wilkins, 1982). As such, the Commonwealth of Virginia has made it a policy to protect and promote the growth of SAV (Chesapeake Bay Agreement, 1987) and has written such policy into subsequent regulation (e.g. 4 VAC 20-335-10 ET SEQ., 4 VAC 20-1010-10 ET SEQ). Unfortunately, the growth of SAV and development of aquaculture can be mutually exclusive uses of the bottom land.

Hard clam aquaculture utilizes large areas of bottom for clam grow-out. The clams are spawned in a hatchery and then placed on the estuary bottom in covered trays in high salinity waters for several months. They are then transferred to larger grow out areas where they are placed directly on the bottom sediments. Large nets, approximately 4 m × 15 m, are placed over top of the clams and then anchored to the bottom with sand bags. Both the nets and the covered trays are designed to protect the clams from predators such as crabs and sting rays. By their presence, they kill existing SAV and exclude the growth of SAV into the area on which they are placed.

Serious concern has arisen about the incompatibility of these two uses of the Commonwealth's bottom lands. SAV interests argue that SAV and potential SAV habitat should be protected at any cost since SAV provides critical habitat for many of the species of the Commonwealth's natural fisheries. Aquaculture interests argue that hard clam aquaculture is a sustainable fishery and lucrative industry that greatly benefits an economically depressed region of the Commonwealth. They furthermore argue that the presence of their clams in the vicinity of grass beds may actually promote grass growth by altering sediment and water quality.

The Habitat Suitability and Management Models

Spatial habitat models, often based upon habitat suitability indices (HSIs), have been developed for a variety of different purposes and in a variety of different regions. Kapetsky *et al*. (1990) developed a spatial habitat model based upon HSIs to predict the best locations for pond aquaculture in Louisiana. Battista (1998) recently developed a model to predict the best locations for optimal oyster growth based upon food availability and disease prevalence in the Chesapeake Bay. A similar model is currently being developed to predict potential SAV habitat to help target restoration efforts in Maryland (Goshorn *et al*., 1998).

An early attempt to look at potential use conflict between shellfish aquaculture and SAV was developed by Grignano (1994) using a geographic information system (GIS). The model was small scale (large area, coarse resolution) and very limited by available data. Grignano (1994) looked at the entire Virginia portion of the Chesapeake Bay and its major tributaries. Levels of potential conflict were indicated for very large zones within this region. Results of that project suggested conflict was likely to be significant primarily at local scales, and emphasized the need to develop higher resolution models and analyses. The current project involves a next iteration of this type of modelling, again using GIS, but focusing on a much smaller region with higher resolution data. The study area in this project is two small creek systems on the Bay side of

Virginia's Eastern Shore. Instead of an analytical scale of kilometres, the current analysis is undertaken at a scale of metres. This more closely approximates the current scale of management efforts.

Materials and Methods and Results

Development of Hard Clam Aquaculture Suitability Index and Spatial Model

The clam aquaculture model is based upon a combination of the biological requirements of hard clams and the industry requirements for growing clams. Clam grow-out nets are located in high salinity (preferably 25–35 ppt) waters (Oesterling, 1996). Areas with hard, sandy sediments and shallow waters (1 metre or less at mean low water) are selected to allow aquaculturists to tend the clams. Macro algal fouling of the nets is common much of the year and the aquaculturists must be able to clear the nets of algae and harvest the clams without sinking into the sediments while wearing chest waders (Pierson, pers. comm.). Finally, clam culture cannot be undertaken in areas condemned for the direct harvest of shellfish by the Virginia Department of Health based on monitoring of fecal coliform levels. For these reasons, the factors selected for the model were salinity, sediment type, bathymetry, exposure, and condemned areas.

The sites in the Chesapeake Bay selected for this study were the Cherrystone Inlet system consisting of Cherrystone Creek and Kings Creek and the Hungars Creek system consisting of Hungars Creek, Matawoman Creek, and The Gulf.

Sediment type in the shallow waters was consequently derived from aerial photography using visual grey scale comparisons and then digitally plotted. Bathymetry was interpolated from NOAA (National Oceanographic and Atmospheric Administration) with the exception of offshore sandbars. Because of their dynamic nature, offshore sandbars were digitized from photographs to provide a more recent coverage than was available from bathymetric data. Preliminary exposure coverage estimates were made using best professional judgment, taking into account fetch and wave breaks from off shore sand bars and land masses (Hershner, unpublished data). Salinity is appropriate at all locations studied for clam culture. Condemned areas are determined and mapped by the Department of Health Shellfish Sanitation Bureau, Virginia. Maps of the coverages for both the Cherrystone Inlet and Hungars Creek systems are included in Appendix 2 off the full report at http://ccrm.vims.edu/projreps/clamaqua_sav.pdf.

The hard clam aquaculture suitability model was generated by ranking conditions within each of the three mapped parameters to indicate probability of supporting the activity. Rankings of the model parameters are shown in Table 1. (Note: Salinity was suitable throughout the study area and therefore not a factor in this analysis).

Table 1 Clam aquaculture suitability model parameter rankings.

	Parameter ranking		
Parameter	**High**	**Medium**	**Low**
Bathymetry	< 1 metre		>1 metre
Exposure *	fetch < 1 km	fetch >1 km + < 2 km	fetch > 2 km
Bottom type	sand		mud
Condemned areas	not condemned		condemned

* Exposure was basically determined by westerly fetches measured to either a landmass or shoal waters < 1 metre.

Clam Aquaculture Model output is mapped in Figures 1 and 2, for Cherrystone Inlet and Hungars Creek respectively.

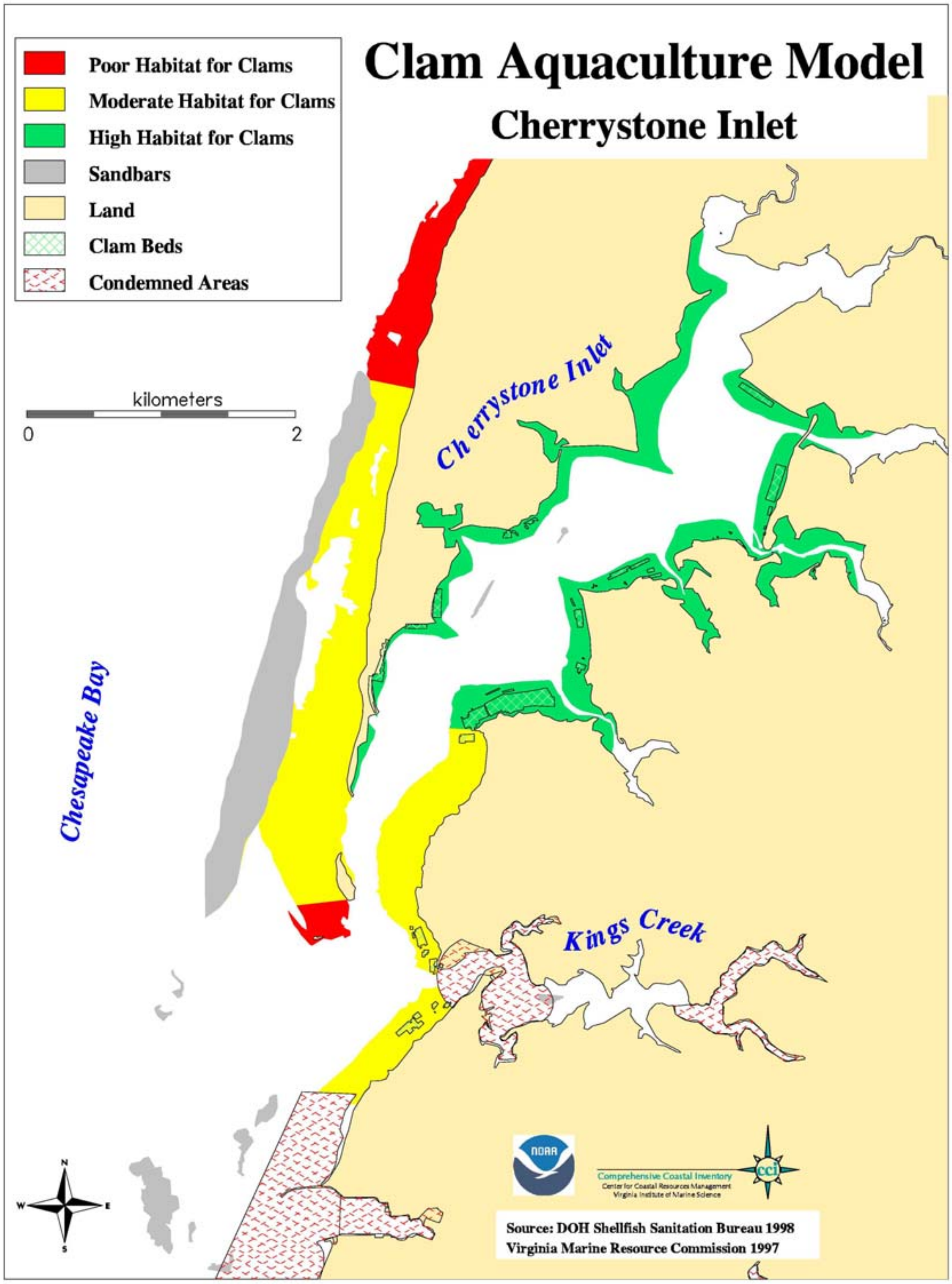

Figure 1 Clam Aquaculture Model – Cherrystone Inlet.

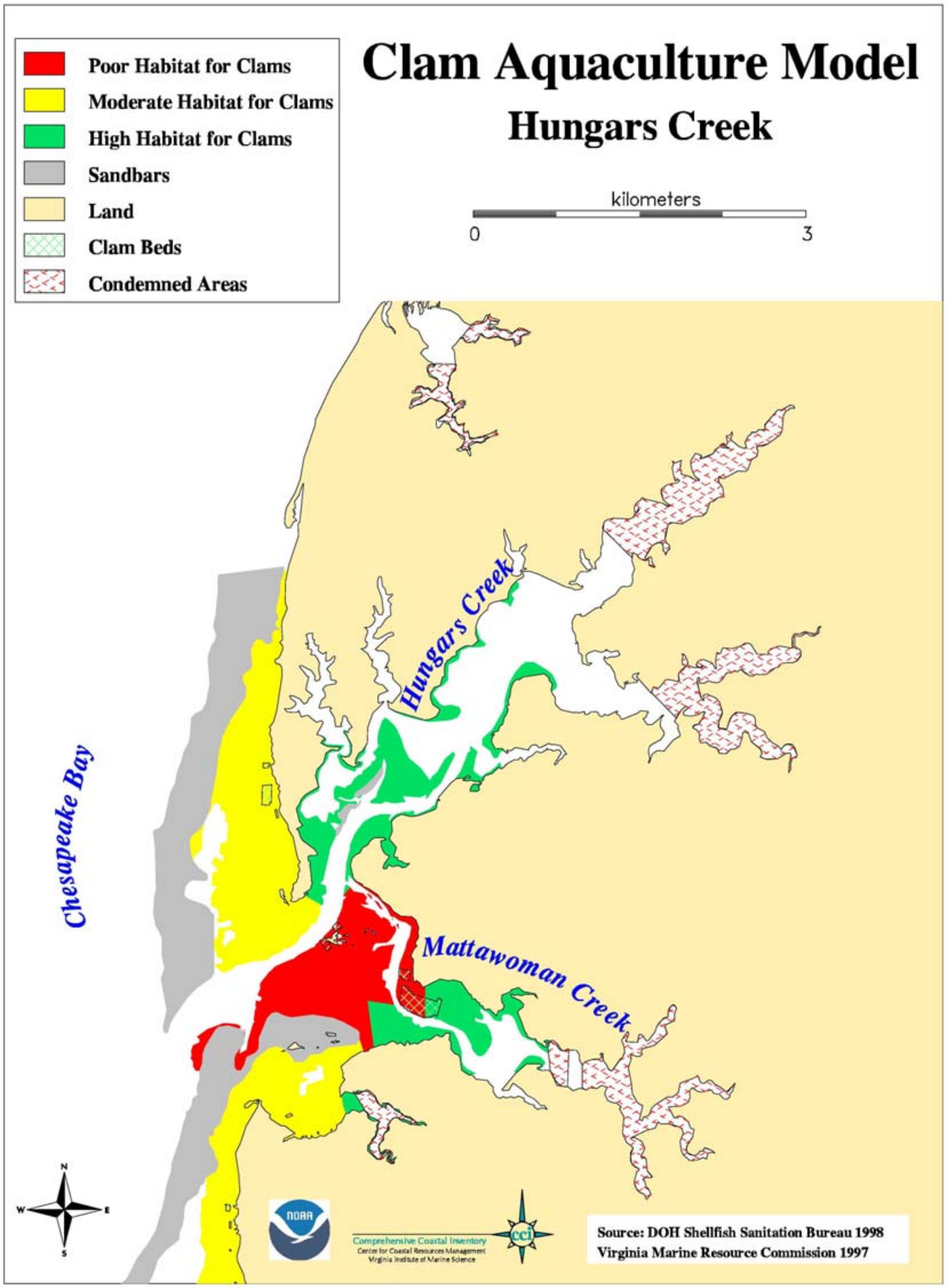

Figure 2 Clam Aquaculture Model – Hungars Creek.

Development of SAV Habitat Suitability Index and Spatial Model

Literature on SAV habitat requirements including Technical Syntheses I and II (Batiuk 1992; Batiuk, in development), were reviewed and experts were consulted regarding the habitat requirements of the SAV species *Zostera marina* and *Ruppia maritima* (Moore, pers. comm.). Factors influencing habitat suitability for SAV in the lower Chesapeake Bay were determined to be water quality, depth, and wave exposure. Several methods of modeling/assessing appropriate water quality for SAV were considered (Table 2).

Table 2 Methods of assessing water quality for SAV.

Method	Accuracy	Data required
Light attenuation	good	light attenuation
TS: 2 of 5 factors	better	nitrogen, phosphorus, TSS, chl A, light
TS2: percent light at leaf surface (PLL)	best*	K_D, DIN, and DIP

*Not thoroughly tested but promoted in TS2 over previous methods.

Available water quality data for this region was collected and light attenuation, in the form of Secchi depth measurements, was determined to be the best available method for assessing required SAV water quality. Although the accuracy of using only light attenuation to determine water quality for SAV is the lowest of the methods described, data required to use either of the other two methods is not available at the spatial resolution needed for this project. The combined data set allowed a first order approximation of light levels in these creek systems with adequate spatial resolution.

Median Secchi depth during the SAV growing season, March through November (Orth and Moore, 1986), was calculated, geographically plotted, and interpolated. Current SAV distribution versus monitored light levels in the study area was used to identify the requirements for habitat suitability.

Since most SAV in the region grows in at a depth of one metre or less (Orth and Moore, 1988), the model was designed to predict suitable habitat for SAV at one meter or less, MLW. Areas with good or marginal light levels where characterized by Secchi disk measurements of 1 metre or less.

GIS coverages for all of the model parameters used are presented in maps in Appendix 2 of the full report at http://ccrm.vims.edu/projreps/clamaqua_sav.pdf.

SAV habitat suitability model parameters were ranked as shown in Table 3.

Table 3 SAV habitat suitability model parameter rankings.

Parameter	Parameter ranking		
	High	Medium	Low
Bathymetry	< 1 metre		> 1 metre
Exposure *	fetch < 1 km	fetch > 1 km + < 2 km	fetch > 2 km
Water quality	Secchi > 1 metre	Secchi = 1 metre	Secchi < 1 metre

*Exposure was basically determined by westerly fetches measured to either a landmass or shoal waters < 1 metre.

SAV Habitat Suitability Model output is mapped in Figures 3 and 4, for Cherrystone Inlet and Hungars Creek, respectively. It was not appropriate to validate the SAV habitat suitability model by comparing existing SAV distribution with predicted habitat suitability in the study area. This is because the suitability model was developed empirically using information from the study area. Validation will require testing in other areas, outside of the study area.

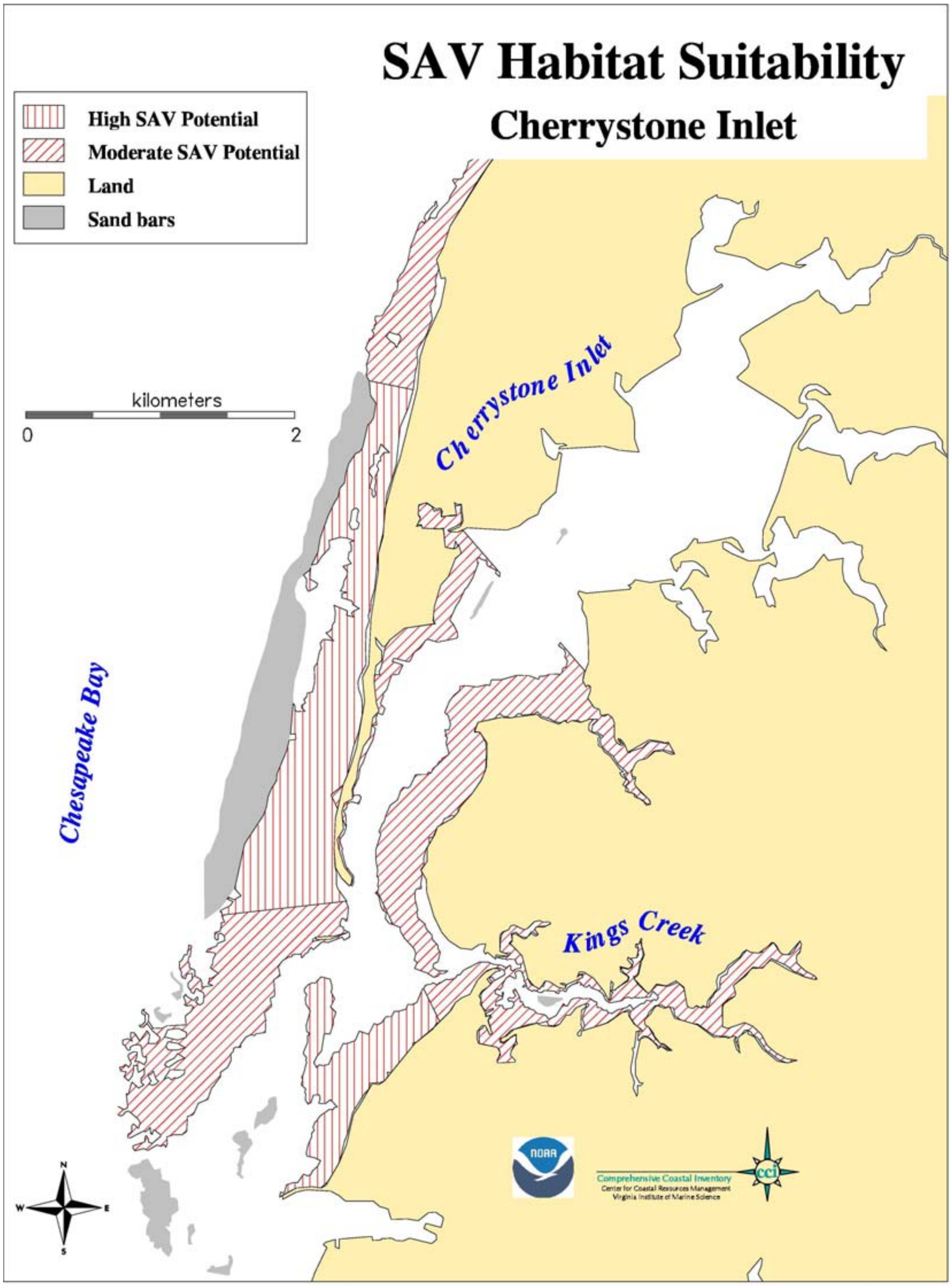

Figure 3 SAV Habitat Suitability – Cherrystone Inlet.

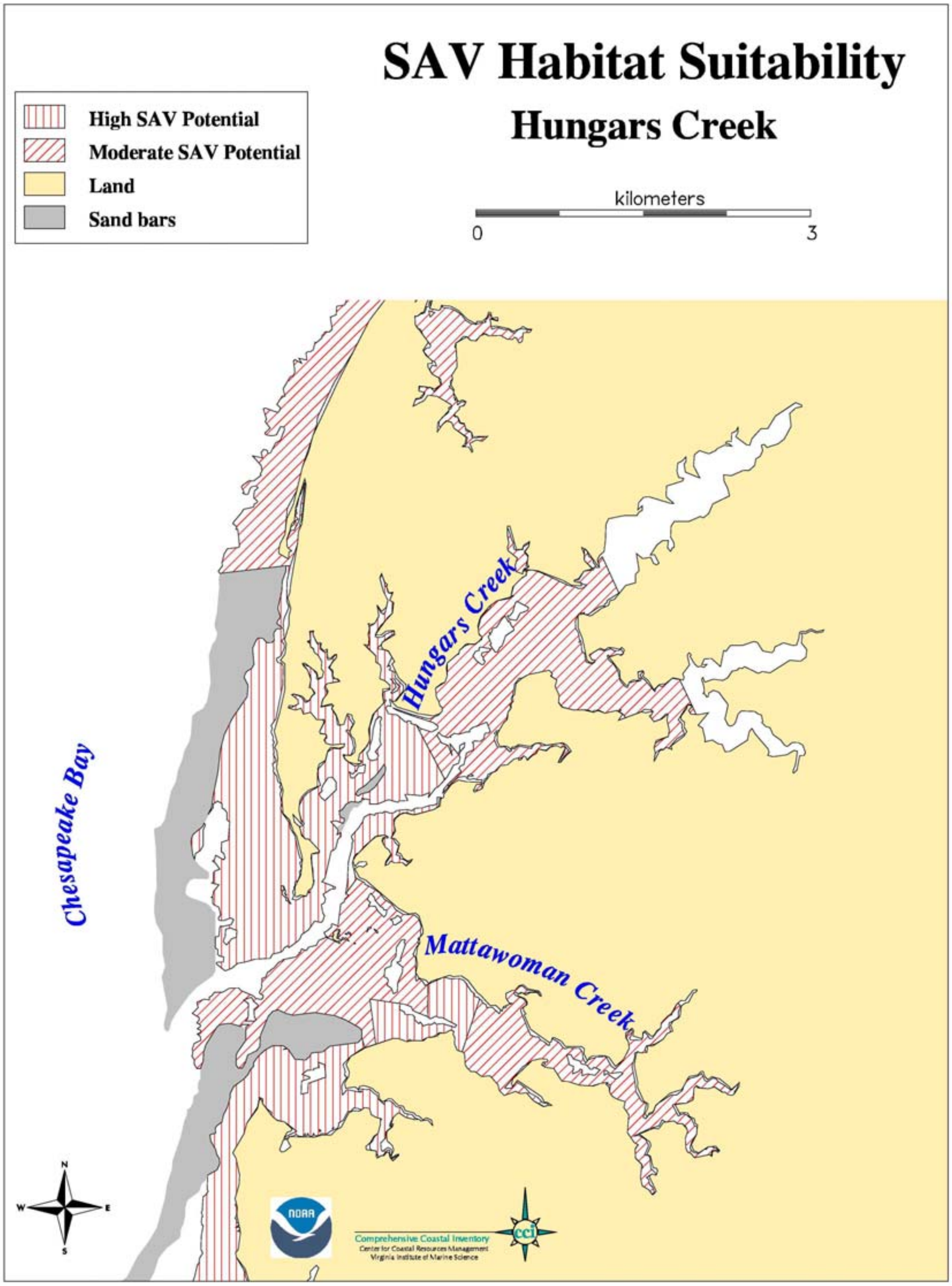

Figure 4 SAV Habitat Suitability – Hungars Creek.

Development of the Conflict Potential Model

The clam aquaculture and SAV habitat suitability models were used to predict areas of relative suitability for each activity/use. The degree of potential conflict was simply modelled by overlaying the derived GIS coverages. The accuracy and precision of this model is dependant upon the accuracy and precision of the clam aquaculture and SAV habitat models. The output of the conflict potential model is mapped for Cherrystone Inlet and Hungars Creek in Figures 5 and 6 respectively.

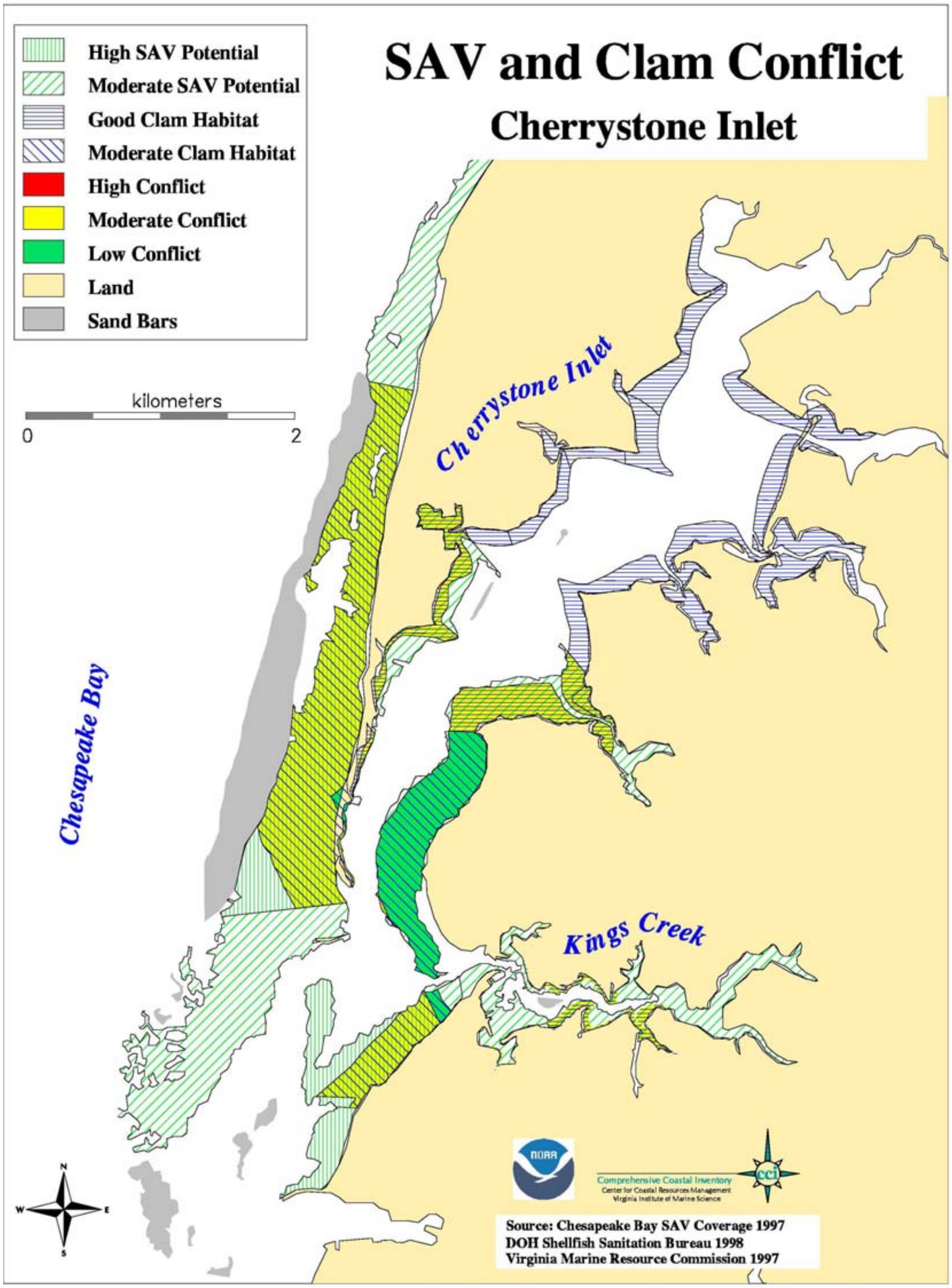

Figure 5 SAV and Clam Conflict – Cherrystone Inlet.

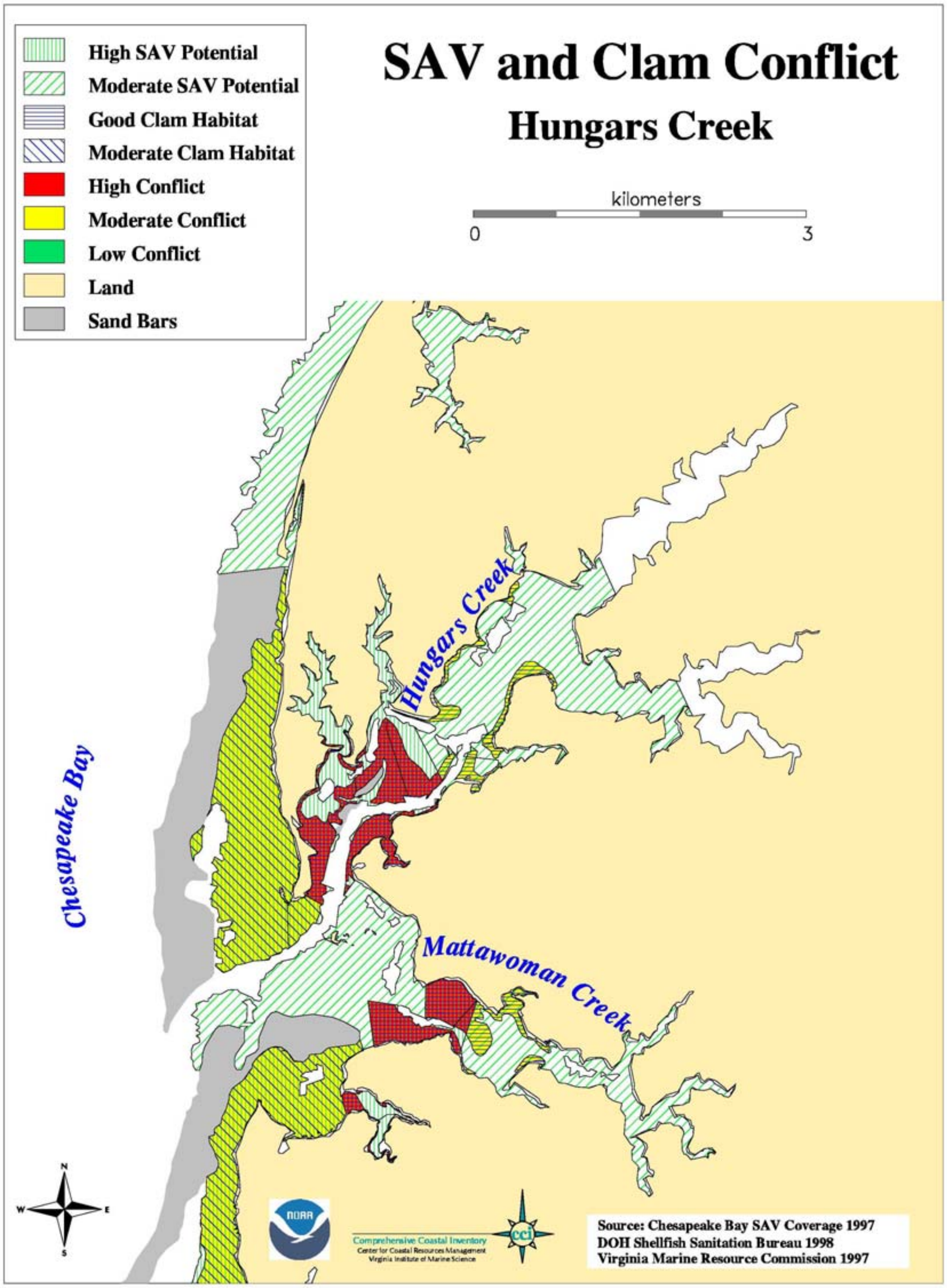

Figure 6 SAV and Clam Conflict – Hungars Creek.

Results of the GIS modelling are presented in Table 4.

Table 4 Areas determined by GIS analysis.

Type of area	**Cherrystone Inlet**		**Hungars Creek**	
	hectares	acres	hectares	acres
Historic SAV	455.8	1 126.3	585.6	1 447.0
Current SAV				
very sparse	144.8	357.8	101.7	251.3
sparse	118.8	293.6	50.3	124.3
moderate	53.1	131.2	21.7	53.6
dense	83.7	206.8	371.9	919.0
total	400.4	989.4	545.6	1 348.2
SAV Habitat Suitability				
high potential	222.9	550.8	414.2	1 023.5
moderate potential	330.9	817.7	509.9	1 260.0
Clam Aquaculture Model				
high potential	194.4	480.4	132.2	326.7
moderate potential	234.1	578.5	253.6	626.6
poor potential	57.0	140.8	109.6	270.8
SAV and Clam Conflict				
high potential	0	0	94.1	232.5
moderate potential	226.6	559.9	283.9	701.5
low potential	60.7	150.0	0	0
Existing Clam Beds	22.4	55.4	10.7	26.4
Existing Private Leases	738.9	1 825.8	495.7	1224.9
Condemned Areas	144.2	356.3	181.6	448.7

Discussion

This study demonstrates an approach to analysis of environmental conditions and use suitability requirements in order to frame policy and management debates. By using existing information, combined with current understanding, simple GIS models have been developed to estimate the distributions of suitable clam aquaculture areas and suitable SAV habitat. By combining the information derived from these two models, and assessment of actual and potential conflict has been developed for a relatively small area.

From the analyses undertaken in this study it appears that the level of existing and potential conflict between clam aquaculture and SAV habitat is not great. At present, monitoring indicates there are a total of 2 337.6 acres of very sparse to dense stands of SAV in the two systems. There are also approximately 81.8 acres of existing clam beds in the two areas. Most of the clam beds are in, or immediately adjacent to, existing SAV beds. At present this represents an overlap of the two activities in approximately 3.5% of the area occupied by SAV.

The potential conflict as estimated by the two suitability models used in this study is significantly greater. The models indicate clam culture could have a moderate or high potential in 2 012.2 acres of the study area, while SAV has a similar moderate to high potential in 3 252.0 acres of the area. If these larger areas were each occupied by the two uses, the potential for moderate or high conflict occurs in approximately 1 493.9 acres, or about 46% of the potential SAV habitat. The difference between the existing and the potential conflict highlights one of the challenges in crafting a policy response to this issue.

Aquaculture may expand if either the market for clams increases, or new types of shellfish or finfish culture are introduced. This will result in increased conflict, even if SAV stocks remain constant. The most likely scenario may be one in which aquaculture is pressed into new areas, as a result of increasing levels of fecal coliform pollution, due to spreading development on riparian lands. Development has the potential to spread condemnation zones further and further down the creeks and inlets, leaving only restricted areas close to the Bay suitable for aquaculture. These are the areas most densely populated by SAV.

There is some evidence (and considerable study) of the possible beneficial feedbacks between adjacent clam and SAV beds. One improves water quality and enhances sediment nutrition, the other reduces sediment suspension and diminishes wave energy. Each potentially creates an environment more conducive to the success of the other. If this turns out to be the case, it may create an argument for a commingling of smaller scale clam culture with SAV. This would be analogous to the selective harvest approach in forestry, in which highly valued material is carefully removed from the midst of forests in a manner designed to preserve the basic forest structure. The policy choice for clam culture comes down to an opportunity to have increased production in potentially high quality environments, in exchange for a reduction in efficiency to distribute impacts and reduce concentrated effects.

This report identifies three basic alternatives for future management strategies. A “do nothing” strategy is acceptable only as long as current conditions are desirable, and the situation is unlikely to change. Long term maintenance of the status quo seems most unlikely as economic and development pressures both undergo constant alterations. The “situational response” strategy is essentially what has gotten Virginia to this point. Establishing new approaches only when existing methods have failed never achieves prevention, but merely attempts remedy. “Proactive management” is a practicable alternative with many variations. Advance planning for resource utilization affords the opportunity to optimize benefits, and considers management efficiencies. While this general approach has many strong technical reasons for selection, it is also the most daunting of the options, because it may require restructure of existing management programs.

As it is our purpose in this report to simply raise policy options based on the background work undertaken here, we will not attempt a comprehensive discussion of the variations possible in a “sustained balance” approach. The first is that no matter how one characterizes the undertaking, at its most basic, any attempt to sustain two competing uses for a spatially limited resource will require some allocation of access. In a word, the resource will have to be “zoned” for the competing uses. The second issue is that when one manages an anthropogenic/economic activity, sooner or later, the permissible efficiency of the operation must be addressed. This usually, and in this particular case explicitly, becomes a question of the desirable scale of operation.

“Zoning” intuitively incorporates some identification of optimal uses. One of the things evident from the current study is that even when our knowledge and data are relatively limited, it is possible to identify areas which are probably most suitable for a given use. If the long term management goal is to sustain a use, ensuring the use can occur in areas where it is most likely to succeed is logical. In the case of clam aquaculture and SAV, this implies each would be afforded some preference in defined areas of the sheltered, shallow, clean water environments of Virginia’s estuarine waters. A key unresolved issue at present is the essential size and distribution of those areas. How big and in what proximity do SAV beds have to be in order to ensure their persistence? How large an area has to be in cultivation for clam farming to be an economically viable undertaking?

Table 5: Policy Option Summary.

Policy option	**Advantages**	**Disadvantages**	**Issues**
Do Nothing	no cost to implement	no conflict avoidance	assumes static conditions
Situational Response	limited investment in management	reactive, does not preserve options	assumes “natural selection” will optimize use allocation
Proactive Management	supports clear policy choice	costs more to implement, requires changes to current policies	informed decision making requires methods for optimization of use allocation
“Zoning”	easily defined and patrolled	requires restructuring existing management	identification of optimal areas for various uses is necessary
“Managed Efficiency”	preserves beneficial feedbacks between uses	more difficult to manage	critical scaling of uses is necessary to ensure sustainability

The current status of clam aquaculture and SAV regrowth in the Cherrystone Inlet and Hungars Creek systems of Virginia’s Eastern Shore is one of low actual conflict, but significant potential conflict. One factor utilized in the models developed for this project will determine the future evolution of this conflict. **That factor is water quality**. Water quality, in terms of nutrients and suspended solids, determines the suitability of an area for SAV growth. Improved water quality means more SAV, decreased water quality means less. The amount of SAV is a direct determinant of potential conflict with clam culture.

These same water quality parameters have similar, although somewhat less precise impact on clam culture. Nutrients and suspended solids impact clam feeding efficiency, with negative impacts at both high and low levels. Another critical water quality parameter for aquaculture is fecal coliform contamination. When fecal coliform levels rise above set limits, areas can be declared off limits for shellfish culture, eliminating otherwise suitable or even desirable regions. Reducing the efficiency of clam growth, or eliminating potential areas for clam culture can each influence the extent of potential conflict with SAV. In one case conflict may be reduced due to reduced levels of aquaculture activity, while in the other case conflict may be increased due to restricted options for locating the activity.

There are other factors, not considered in the models, which will also influence the degree to which conflict is realized. Two major factors are change in the size of the clam aquaculture industry and change in the current management strategy. Market growth or decline for cultured clams will obviously influence the demand for area dedicated to the activity, and thus the potential for conflict with SAV. The degree to which the two uses of subaqueous lands are allowed to come into conflict will be determined by the management strategy implemented.

It is beyond the scope of this report to fully assess the strengths and weaknesses of alternative strategies. We have demonstrated, however, that the need for effective strategies has arrived. The level of current conflict between two equally desired uses of subaqueous lands is not high. But the potential for future conflict is significant, and nothing in the current management toolbox is suited to reducing or directing the evolution of that conflict.

As a final note, proposals to modify existing regulatory approaches for management of shellfish aquaculture operations are not new. Assessment of needs and options has been an ongoing activity at the highest levels of Virginia government (VMRC, 1996). The work undertaken in this project simply adds additional information combined by GIS models and analysis, contributing to the debate, and possibly additional impetus for action. It is interesting to note that the study area for this project encompasses some of the most intensive aquaculture activity, the most persistent and productive SAV beds, and some of the most extensively leased subaqueous lands in the Commonwealth (see Figures 7 and 8 at the web site:
http://ccrm.vims.edu/projreps/clamaqua_sav.pdf).

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