GIS and commercial bivalve fisheries

Aquaculture is an ever growing industry in our country and as its breadth expands it is becoming extremely important to maximize the efficiency of our farming facilities. Marine organisms require very specific environmental parameters in order to flourish in these facilities or in the open ocean. For example, when farming commercial bivalves it is important to take into account the food availability, hydrodynamics, and temperature of the rearing environment (Bacher et al., 2003). To maximize commercial shellfish farming output, it is essential to choose the appropriate farm location. The integration of underwater surveying techniques along with Geographic Information Systems technology can assist commercial bivalve farmers not only in choosing the appropriate site for their farms, but also in assessing the health of their current farming locations. This paper details the use of various surveying techniques that can be used in conjunction with Geographic Information Systems technology to enhance the commercial bivalve industry.

First and foremost it is essential to ensure that your environmental data is in a format that can easily be transferred to GIS when integrating these two data formats to assess habitat. Smith and Greenhawk (1998) examined multiple techniques for surveying benthic habitats in the Chesapeake Bay in hopes to determine which technique provides the most accurate substrate information and which technique is most easily integrated with both GIS and GPS technologies. This study provides an excellent overview of various surveying techniques that could be used to obtain relevant environmental data. Multiple data collection techniques were examined including acoustic sub-bottom profiling, side-scan sonar, underwater video, sediment analysis, and Seafloor Classification Systems. Each of these techniques exhibited some costs and benefits, however the most valuable technique was found to be Seafloor Classification Systems. Seafloor Classification Systems provide accurate real time data, are within the price range of the average scientists, and can be easily integrated with GIS and GPS technologies (Smith and Greenhawk, 1998). This study provides an excellent starting point for performing benthic habitat analysis using GIS.

Smith et al. (2001) continued to utilize GIS technologies by digitizing the Maryland Bay Bottom Survey (MBBS) to assess the depletion of oyster habitat in the Chesapeake Bay. Using GIS, Smith et al. (2001) were able to compare the MBBS to the 1912 Yates survey. Through this study they determine that the MBBS provides an accurate assessment of the oyster habitat and they were able to estimate the loss of habitat over the century. This extension of GIS analysis is extremely helpful when monitoring the state of our fisheries. Through dataset development, aquaculture facilities can maintain and track the health of their crop and they can easily display changes that are occurring within the fishery.

GIS can also be utilized by commercial bivalve farmers to choose the most appropriate location in which to set up a farming facility. The study
performed by Parker et al. (1998) was one of the earliest to utilize GIS in combination with environmental modeling to determine the best sites for shellfish habitat. Parker et al. (1998) obtained data from a variety of sources and estimated the tidal heights and current velocities using a Princeton Oceanographic Model for Mason Bay, Maine. This model was then integrated with GIS technology to visually display the data and assess the habitats in Mason Bay to find the most appropriate sites for aquaculture by developing specific queries. Congleton et al. (1999) extended this original study by combining the modeling data with aerial photography. This allowed them to enhance their dataset further by providing more detailed information regarding the intertidal zone of the bay. Accuracy tests were performed and it was found that the models were accurate estimates of the environmental parameters.

GIS was an excellent tool to use in habitat assessment because it allows aquaculturists to visualize and analyze spatial data under a variety of conditions. Multiple queries can be performed on different permutations of the data. For example, in some shellfish aquaculture sites the bottom type may be the most important environmental characteristics, whereas in other location it may be necessary to maximize flood tide current velocity (Congleton et al., 1999).

Arnold et al. (2000) utilized GIS to examine the existing hard clam (Mercenaria spp.) farms present in the Indian River Lagoon, Florida. Sites for hard clam fisheries are leased out by the State of Florida. Arnold et al. (2000) detailed the habitats in the Indian River Lagoon by mapping environmental characteristics and using overlay procedures on existent GIS data for this lagoon. The State of Florida has since adapted this dataset to determine how many lease sites are available within the lagoon and to delineate between individual lease sites. The success of this analysis in the Indian River Lagoon led Arnold et al. (2000) to extend this study to include Charlotte Harbor, Florida. Hard clam fisheries have not yet been developed in Charlotte Harbor, yet 6321 ha of potential clam harvesting habitat was identified (Arnold et al. 2000). In this case, GIS analysis provided the State of Florida not only with a valuable assessment of current hard clam fisheries, but it also increased the extent of this important Florida fishery and proved to be extremely profitable to the state.

In all of the cases presented so far, scientists have focused on locations wherein only one fishery exists. Bacher et al. (2003) utilized GIS technologies to examine carrying capacity in Sungo Bay, China wherein scallops are only one of the major commercial crops. Sungo Bay supports not only a major scallop fishery but also both an oyster aquaculture center and kelp aquaculture facilities. In recent years the scallop crop has decreased in productivity possibly due to depletion of food and nutrients in the bay (Bacher et al., 2003). By modeling these parameters in conjunction with other environmental variables, Bacher et al. (2003) tried to determine whether the bay is past carrying capacity.

The model was originally used to examine the spatial variability in various environmental parameters and to determine what effect these parameters had on the commercial scallop industry. However, the model can now be extended to not only maintain the scallop industry, but also to examine the health of both the oyster and the kelp aquaculture facilities within the bay. Due to the
overexploitation that is occurring in the bay (Bacher et al., 2003) it is necessary for scientists to develop more effective aquaculture strategies. These strategies can also be developed with the use of GIS.

Not only has GIS been used to help find suitable sites for shellfish habitat and to assess the health of various fisheries, but it has also been used to visualize and track pathogens within certain shellfish populations. White et al. (1998) integrated GIS and kriging analysis to detail the spread of *Perkinsus marinus* in the South Carolina oyster population. By integrating spatial environmental parameters and presence of the oyster pathogen, it was determined that the prevalence of this disease corresponds with various land characteristics. With further integration and development of surveying tools scientists will soon be able to better understand how this pathogen travels through the oyster population and how it can possible be controlled or stopped.

Although the introduction of GIS to the marine realm and commercial bivalve industry is fairly new, it has been shown that the use of GIS technologies is essential for the planning and maintenance of aquaculture facilities. With this technology, aquaculturalists can enhance the health and production of their crop. With the publicity of these studies, hopefully more scientists will begin to use this technology for habitat assessment purposes. Also, the use of GIS and these types of datasets could be extended to census the organisms within a habitat, to describe various microhabitats, to track environmental conditions through time, and to examine the impact of changing land characteristics on intertidal environments. The possibilities are limitless and hopefully will be extended with time. GIS is a tool that could be used to enhance our understanding of community structure and change in the marine realm.

**Annotated Bibliography**


Arnold et al. used GIS to identify sites that have the appropriate environmental conditions for the aquaculture of the hard clam *Mercenaria spp.* in Florida. A subset of both the Indian River Lagoon and Charlotte Harbor was deemed appropriate for this type of aquaculture using very specific query parameters. The State of Florida has since used the results of this study to determine which areas can be leased commercially for aquaculture purposes. The most interesting part of this study was the results of the query and the detail in which they can describe various sites within the two study areas. This article was visually appealing and the procedures were well-described.

Bacher et al. modeled various environmental parameters to estimate the effect of food depletion on scallop growth. They found that both food concentration and current velocity were important in determining the quality of the scallop harvest. The integration of these models with a GIS program allowed the authors to visually identify the effect of each parameter. Although the results of this paper were interesting, I found the modeling methods difficult to follow.


Congleton et al. integrated topographic, bathymetric, photographic, and modeled velocity data into a GIS framework which was used to specify appropriate sites in an intertidal bay in Maine for shellfish mariculture. They found that using the combination of GIS and numerical modeling allowed them to easily specify locations within the intertidal zone in which various organisms would thrive. The most interesting part of this paper was the description of the methods used to transform point elevation data into a 3D polygon coverage and elevation grid.


Parker et al. organized various environmental parameters into a GIS program to examine the survival and growth of clams in Mason Bay, Maine. Parker et al. used a Princeton Oceanographic Model to estimate the current velocities and the distribution of chlorophyll A in the bay. The most interesting part of this research involved the modeling of current velocities at different tidal heights. I found that the use of GIS to visually display this data was extremely helpful in the presentation of this research.


Smith et al. utilized GIS as a tool to compare oyster habitat from Yates 1912 to MBBS ~1980. They describe the methodology used to collect habitat information for the MBBS mylars, the digitization of these mylars, and the methods used to compare the two datasets (1912 to 1980) and the MBBS data to the natural environment. The detail provided regarding the techniques used to check their interpretations was quite interesting. Overall, they found that the MBBS dataset appropriately described the habitat and I was most impressed that the authors were conscious of the limitations of this data and were quick to provide insight in the appropriate uses of this dataset.

Smith and Greenhawk examined a slew of techniques used to survey the sea-floor of the Chesapeake Bay. They then examined the ability of each of these techniques to be integrated into with both GPS and GIS to find the most effective method of assessing oyster habitat. Their discussion of surveying methods was quite informative and well-described. However, from their discussion it remains clear that improvements are still required to fully and accurately characterize the benthos.


White et al. combined GIS and kriging methods to characterize the distribution of an oyster pathogen within two South Carolina estuaries. Through these analyses they determined that the prevalence of the pathogen is correlated with land use characteristics of the nearby shore. They also believe that with some advancement, they may be able to predict the movement of this pathogen through the oyster population. From this paper it is clear that kriging can be a useful tool for turning a discrete sample into a continuous spatial dataset. Although the paper is interesting and provides insight into a new data massaging tool, I found that I wanted more detail than was provided.