Southern California Aquaculture Site Assessment Model
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Abstract

The Southern California Aquaculture Site Assessment Model (SCASAM) project demonstrated a geographic information system (GIS) based methodology for performing a multi-dimensional site assessment for open ocean shellfish mariculture. Using publicly available data, the project employed a multi-criteria approach in two phases: an economic and logistical assessment, and a water column environmental conditions analysis. The economic and logistical assessment incorporated legal restraints on site placement, and bathymetry and proximity considerations for infrastructure support and transportation to create suitability delineated zones in ArcMap. The environmental assessment, conducted in ArcScene, explored the water column data for the suitable and optimal living conditions for the California mussel (*Mytilus californianus*). The environmental analysis considered temperature and salinity distributions, oxygen saturation, and chlorophyll concentrations.   The assessment was completed for two California Cooperative Oceanic Fisheries Investigation (CalCOFI) sampling sites. Water conditions at both sites showed the ability to support California mussels throughout the water column throughout the year. In addition, optimal conditions were found from the surface to five meters below throughout the year with the depth extending deeper seasonally.

Introduction

The Southern California Aquaculture Site Assessment Model (SCASAM) project was guided by Mr. Drew Stephens, the Esri Ocean and Coastal Industry Solutions Manager. It developed out of an inquiry by Mr. Phil Cruver, the president of KZO Sea Farms, about the possible use of GIS technology in the Catalina Sea Ranch project. The Catalina Sea Ranch project is a new mariculture venture, which would be the first federally permitted commercial open ocean mariculture operations in the United States. Since the Catalina Sea Ranch project is still in development, the SCASAM project needed to use open source data to demonstrate applying GIS to understand and evaluate site suitability.

While the United States mariculture industry has used GIS in its coastal ventures before, the shift to open ocean sites has created a new set of spatial problems to address. One of the primary concerns of the industry is selecting and situating farming structures within off-shore sites. Mariculture siting considers the logistical needs of building, maintaining, and running an aquaculture operation, as well as the biological needs of the fishery. In addition, open ocean aquaculture has to understand a site's water column in order to determine the optimal depth to submerge farming structures (Gifford, Benetti, & Rivera, 2011).

The SCASAM project developed a process for a three-dimensional site assessment for mariculture, primarily based on the Catalina Sea Ranch parameters. In order to do so, the project developed a methodology to conduct a complete site assessment using commercial off-the-shelf solutions in ArcMap and ArcScene using Model Builder and other geoprocessing tools. The project compiled a geodatabase of key logistical factors for supporting mariculture ventures in Southern California including marine protected areas (MPA), shipping and navigation

channels, and port and fish processing facilities. The project developed a methodology for exploring oceanic water columns conditions using data from the California Cooperative Oceanic Fisheries Investigation (CalCOFI) in a realistic and easily understandable representation.

Background

Historically, the primary application of GIS to aquaculture has been in site selection. One of the first significant GIS-based aquaculture site selection cases was a 1987 siting analysis conducted for the Gulf of Nicoya by Kapetsky, McGregor and Nanne. The study considered multiple types of aquaculture for mollusks and shrimp. The analysis considered various ecosystems for placement including salt ponds, and intertidal and subtidal ranges. The Gulf of Nicoya study popularized a practical example for using GIS for aquaculture siting that most modern studies are based on (Valavanis, 2002).

Site assessments differ from study to study based on the weighting and definition of different factors. It can be difficult to determine which factors are the most significant to a site's analysis. In fact, a site selection study for oyster raft culture in Venezuela found that weighting of different factors could potentially be one of the most important and difficult analysis variables to define (Buitrago, Rada, Hernandez, & Buitrago, 2005). After talking to over 18 fisheries experts, the 2005 Venezuela study's factor weighting variance-to-mean ratio was 1.66, indicating a large variability in analysis construction even amongst field specialists. This wide variation in factor weighting makes creating a universal approach for aquaculture siting difficult.

Data

The SCASAM project used California Cooperative Oceanic Fisheries Investigation (CalCOFI) water sampling data to simulate site water sampling by a mariculture venture for biological suitability considerations. CalCOFI is a joint research venture between NOAA, the California Department of Fish and Wildlife, and the Scripps Oceanographic Institute. CalCOFI samples certain sites off the coast of Southern California using a conductivity-temperature-depth sensor with an accompanying rosette. The samples are tested for a wide range of environmental factors including, but not limited to, salinity, oxygen saturation, and nitrate, nitrite, phosphate, and chlorophyll concentrations.

For the economic and logistical data sets, the project collected data from a wide variety of sources. While the assessment used multiple data sets, the MPAs, shipping and navigation channels, and bathymetry were pivotal to the analysis. The MPA boundaries were retrieved from NOAA's National Marine Protected Areas Center (2012). The shipping and navigation channels were retrieved from State of California's CalAtlas (2012). Bathymetric was taken from the Southern California Ocean Observing System as points and converted into bathymetry contours and digital elevation models using ArcGIS geoprocessing tools (Divins and Metzger, 2013).

The data processing and visualization was completed in Microsoft Excel, ArcMap, and ArcScene. The logistical data were collected as shapefiles or geodatabase files and directly imported into a common file geodatabase. The CalCOFI site data were provided in two Microsoft Excel spreadsheets: one file containing latitude and longitude coordinates and surface conditions, and one file containing water column data. The two CalCOFI files were then imported and joined in ArcCatalog. All of the data used in the SCASAM project were publicly available and free for general use.

Economic Analysis

The economic analysis created five distinct zones for aquaculture siting: restricted, preferred exclusion, acceptable, desirable, and most desirable (Figure 1). The restricted and acceptable zones were based on legal siting requirements and restrictions. The restricted zone was created by merging Marine Protected Areas, navigation and shipping channels, and security zones. The acceptable zone was based on the legal definition of United States national waters and is a 12 mile buffer around the United States coastline.
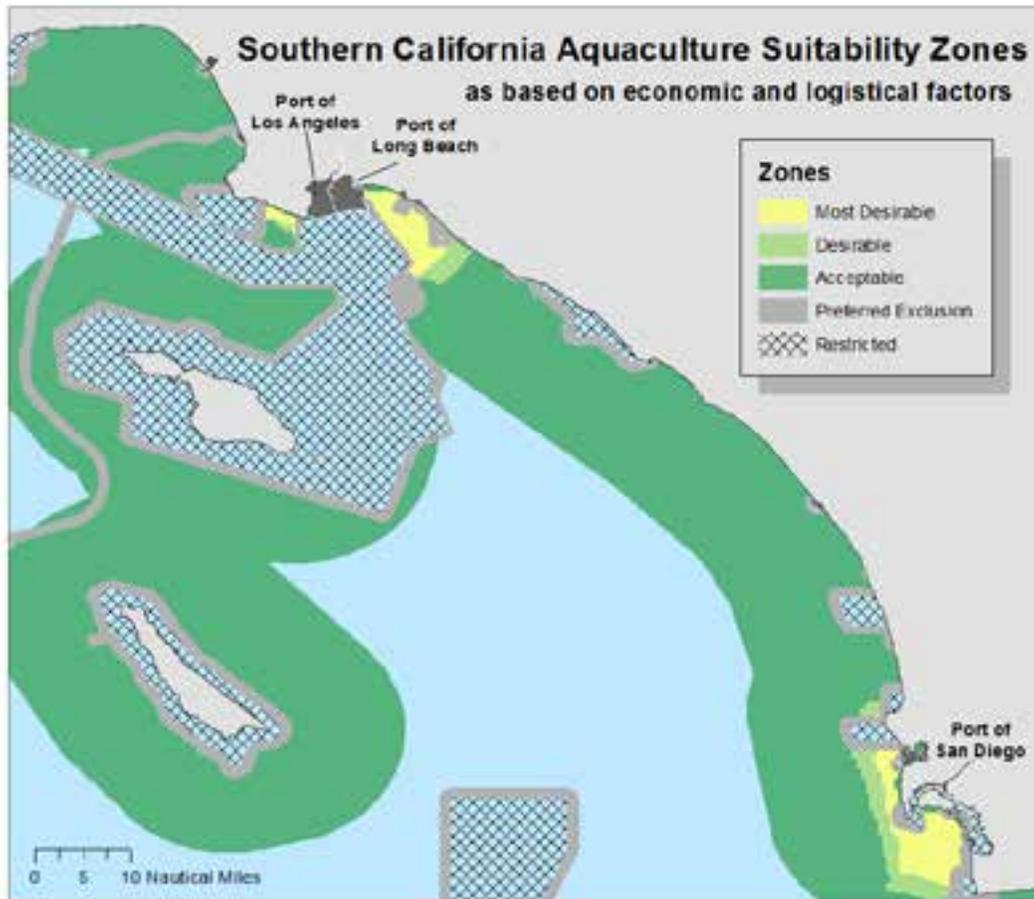

Figure 1. Southern California Aquaculture Suitability Zones as based on economic analysis results

The preferred exclusion, desirable, and most desirable zones were created based on logistical preferences for an aquaculture venture. The preferred exclusion zones are less logistically desirable areas, but still legally viable for aquaculture siting. These areas include one nautical mile buffers around the restricted zones and various buffers around other facilities, such as submerged cables and oil platforms. The desirable and most desirable zones identify areas that can easily support aquaculture infrastructure. The areas identified are within a desirable depth range for mariculture farming structures and proximity to major harbors with fish processing and shipping facilities.

Environmental Analysis

        The environmental analysis was conducted using CalCOFI water sampling data. Two sites were selected based on their geographic proximity and similar depth profiles to the areas that the Catalina Sea Ranch is currently interested in developing. The "Venator" site, CalCOFI Site 088.5 030.1, is approximately one and one half nautical miles west from Huntington Beach, CA and the Lacus site, CalCOFI Site 090.0 028.0, is approximately two nautical miles south from Laguna Beach, CA (Figure 2).
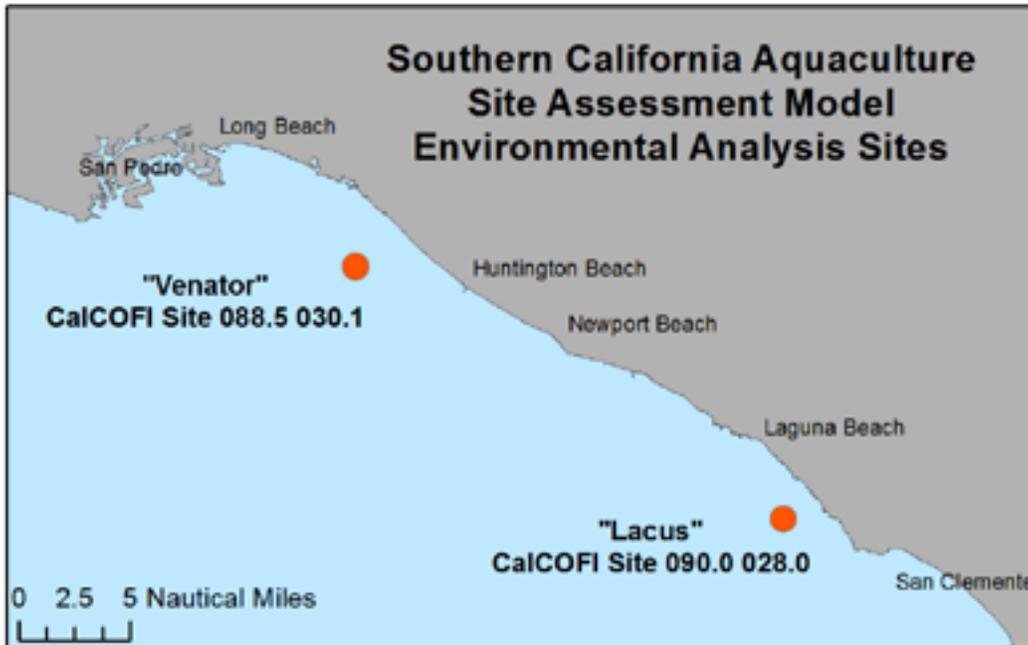

Figure 2. Southern California Aquaculture Site Assessment Model Environmental Analysis Sites

        The environmental analysis conducted in ArcScene looked at temperature and salinity distribution, chlorophyll concentration, and oxygen saturation throughout the water column at two different sites. Since the California mussel is a resilient animal that is adapted this environment, the water column showed the ability to support the mussels throughout the water column year-round (Figure 3). However, there are certain conditions that can maximize mussel growth and are therefore optimal conditions to sink the aquaculture equipment. The Venator water column profile showed that these conditions existed throughout the entire water column on a seasonal basis. The Lacus water column profile showed optimal conditions existing above five meters below the surface throughout the year. In addition, optimal conditions existed above ten meters below the surface on a seasonal basis at the Lacus site.
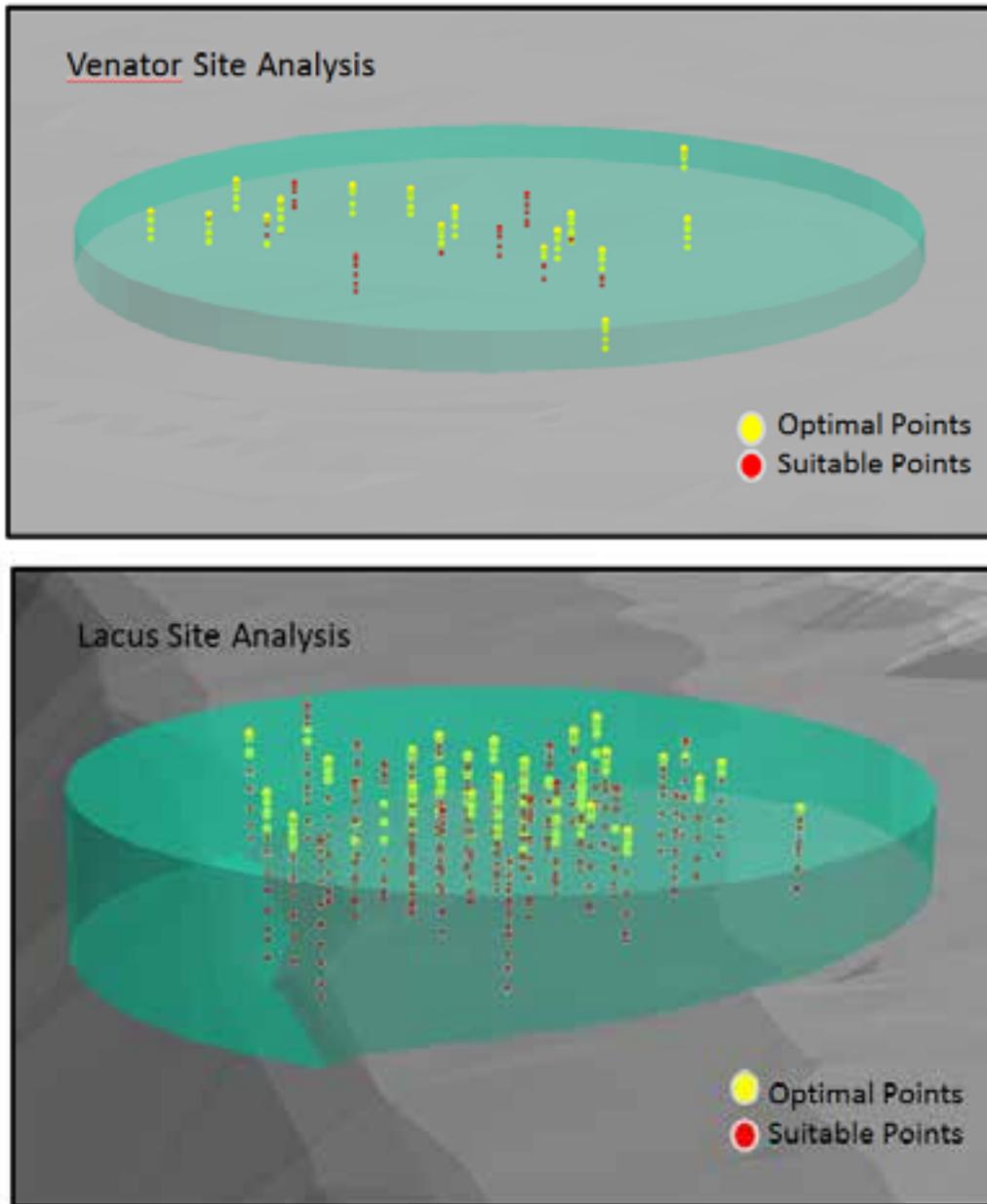
Figure 3. Site classifications for the Venator and Lacus sites based on environmental analysis classifications

Conclusions

The SCASAM project demonstrated that a multi-criteria approach is just as effective with multidimensional data as with traditional two-dimensional data for Southern California. As it can be easily modified, it can account for a wide variety of economic and environmental considerations. In a constantly changing environment such as the ocean, flexibility and customization are important factors when choosing a decision making model. The CalCOFI data are very similar to data sampling techniques that would be employed by an aquaculture firm.

The SCASAM project proves that GIS is a valuable tool for aquaculture siting even in a multidimensional environment.

Works Cited

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