GEOSPATIAL MODELING APPROACH FOR PREDICTION OF POTENTIAL SAV HABITAT INCREASE WITH RESTORATION EFFORTS

Hyun Jung Cho, Department of Biology, Jackson State University
Christopher A. May, Grand Bay National Estuarine Research Reserve

Introduction

The decline in coastal environmental quality is a major global conservation problem (Bell et al. 1993; Short et al. 2001). Efforts to restore coastal environmental quality have been rapidly increasing. Restoration success is not simple to measure, especially when records on the original habitat condition are absent or scarce (Short et al. 2001). Ecological indicators and restoration goals need to be defined first (Richter et al. 1996). Submersed aquatic vegetation (SAV) is a critical fish and wildlife habitat and an excellent indicator of aquatic environmental quality (Dennison et al. 1993).

Potential SAV (PSAV) habitat is the area that supports SAV on an occasional or a regular basis. Although areas that once supported SAV are given some protection from future degradation, usually only areas with actual SAV beds are considered in conservation efforts. This generally results in the further degradation of potential SAV habitat rather than enhancement of habitat quality needed for restoration. Therefore, locating the potential SAV habitat and possible habitat improvement sites in an estuary is critical in a conservation, restoration, or management program.

The potential habitat was modeled in Lake Pontchartrain, LA to predict SAV changes based on changes in water transparency, water level fluctuation, and shoreface slope (Cho and Poirrier 2005). Model parameters were developed from the following results: (1) annual mean water clarity controls SAV colonization depth ($Z_{max} = 2.3 / K_d$); (2) annual mean water level and its fluctuation determine SAV minimum colonization depth ($Z_{min} = 0.3$ m); and (3) site differences in SAV areal coverage under the comparable water quality conditions are due to shoreface slope differences (θ). The equation developed for the Lake Pontchartrain potential SAV habitat model is $PSAV = (2.3 – 0.3 \times K_d) / (\sin \theta \times K_d)$ where K_d is the vertical absorption coefficient; and it was validated by comparing field data to values predicted by the model (Cho and Poirrier 2005). The general form of the model is $\{\ln (I_0 – I_{Zmax}) – K_d \times (MHW-MLW) / 2\} / (\sin \theta \times K_d)$, where I_0 is the mean irradiance at the water surface, I_{Zmax} is the mean irradiance at Z_{max}. The general model can be applied to other coastal habitats if the SAV light requirements, water level fluctuation, and bathymetric structure are substituted for Lake Pontchartrain values.

In western Grand Bay, MS, one of the National Estuarine Research Reserves (NERRs), SAV grows in the areas that are relatively protected from waves. Currently, two SAV species are found in Grand Bay NERR, Wigeongrass (*Ruppia maritima* L) and Shoalgrass (*Halodule wrightii* Aschers). Both *R. maritima* and *H. wrightii* are known as colonizers and opportunistic species (Patriquin 1975; Orth and Moore 1988). They are the first to colonize bare areas after disturbances, fast-growing, and fringe species that grow in shallower water or earlier in the season when occurring with more stable seagrasses of climax communities such as Turtlegrass (*Thalassia testudinum* K.D. Koenig). Due to the absence of stable species, the Grand Bay NERR SAV community displays considerable annual and seasonal variations in aerial coverage and biomass.

We have initiated SAV depth distribution surveys and photosynthetically active radiation (PAR) measurements at Grand Bay NERR with the intention of applying the PSAV model using the NERR survey data. Our objectives are: (1) delineation of current potential SAV habitat; (2) identification of the feasible restoration areas; and (3) prediction of the extent of SAV habitat gain with a unit water clarity improvement.

Methods

Boat surveys were conducted in May and June 2005 to locate feasible transect survey sites. Five sites were selected to represent gradients of shoreface slope (gradual—steep), salinity (depending on the proximity to freshwater sources vs. the open ocean), and tidal (or wave) fluctuation. The sites were marked by polyvinyl chloride posts (Table 1). The coordinates at the sites were recorded using a GeoXT global position system (GPS) (Trimble Navigation Ltd, Sunnyvale, CA) in June 2005.

At Sites 1, 3, 4, and 5, three replicates of transects that are parallel to each other and perpendicular to the shore were extended using reel measuring tapes and metal posts. At Site 2, one transect, instead of three, was used as a reference. We snorkeled along the transects to record the SAV depth distribution (the depths where SAV patches of each species are located). Water depth was measured along the transects at three meter intervals. The surveys were conducted using the fixed transects in June and July 2005.

Table 1. The geographic coordinates for SAV survey sites at Grand Bay NERR, MS, 2005.

Site number	Latitude	Longitude	Location
Site 1	30.3828 N	88.3983 W	Middle Bayou
Site 2	30.3853 N	88.4006 W	Middle Bayou
Site 3	30.3617 N	88.3988 W	Grand Bay
Site 4	30.3523 N	88.4093 W	Point aux Chenes
Site 5	30.3555 N	88.4108 W	Point aux Chenes

Measurements of PAR have been made at water depths of 0 m, and 0.5 m or 1.0 m at three locations near the survey sites twice a month since September 2005. Water transparency also has been monitored biweekly using a Secchi disk at the three locations since July 2005. Daily high and low tides and the corresponding time, collected at one of the National Oceanic and Atmospheric Administration and National Ocean Service Tide Stations (30^o 20.0'; 88^o 32.0') were obtained from a website (http://www.coms.usm.edu/MStide/)

Data analyses

Prior to the following analyses, water depth was calibrated to the mean water level. The data were analyzed as follows to determine the model parameters.

1. Water transparency and maximum colonization depths
   The maximum depths of the SAV species (Z_{max}) were identified from the transect survey data. An assumption was made that the light levels at the Z_{max} are the local light requirements for the species. Since we did not have the entire 1-year PAR dataset preceding the SAV surveys, we assumed the light requirement of Grand Bay *R. maritima* is the same as in Lake Pontchartrain (10% of annual mean PAR at water surface; therefore, $Z_{max} = 2.3/K_d$). Then, we calculated the annual mean K_d from the equation.

2. Tidal fluctuation and upper depth limit for SAV growth
   The minimum depths of the SAV species (Z_{min}) were identified from the transect survey data. Mean tidal fluctuation {(MHW-MLW)/2, where MHW is monthly high water and MLW is monthly low water} during the period of January – July 2005 was calculated using the daily tidal data.

3. Shoreface slope and the distance between the Z_{min} and Z_{max}
   The water depth measurements, made at 3-m intervals, were plotted against the corresponding distance from shore for each site. The shoreface distance between the Z_{min} and the Z_{max} were determined for each site. Assuming a linear trend, the shoreface slope angles were derived from the distance (m) and the water depth (m) at the maximum SAV growth limit.

4. Prediction of the extent of SAV habitat gain with a unit water clarity improvement
   The parameters developed as described above were applied to the PSAV model. The model was used to predict the habitat gain at the site from a 20% K_d reduction (a water clarity improvement).

Results and Discussion

The Z_{max} was 1.1 m for Site 1, 0.9 m for Site 2, 1.25m for Site 3, and 0.8 m for Site 4 in summer of 2005 when the depth data were adjusted to the mean water level. At Site 5, *H. wrightii* Z_{max} (1.2 m) was slightly higher than *R. maritima* Z_{max} (1.0 m). The estimated annual mean K_d values ranged from 1.8 (Site 3) to 2.3 (Site 4) based on the Z_{max} data.

The empirical SAV Z_{min} values from the transects were 0.35 m at Site 1, 0.22 m at Site 2, 0.07 m at Site 3, 0.40 m at Site 4, and 0.50 m at Site 5. The estimated mean tidal fluctuation at the NOAA/NOS Tide Station was 0.46 m.

The shoreface slope angles (θ) in radians for Sites 1 through 5 were 0.006, 0.005, 0.007, 0.004, and 0.02, respectively. Site 5 had the steepest shoreface slope; the extent of SAV growth was greater at Sites 1 through 4 (200 m out or more) than at Site 5 (less than 60 m from the shore).

According to the Z_{min} and Z_{max} values, Site 3 had the lowest water level fluctuation and K_d, which indicates that this site is less subject to wave stress compared to the sites in Point aux Chenes Bay (Sites 4 and 5). SAV depth distribution at the two sites in Middle Bay, Sites 1 and 2, indicates low water level fluctuations, but low water transparency. The water depth of the entire bay (Middle Bay) is seldom deeper than 1.2 – 1.3 m at the mean water level; a 20 % K_d reduction will result in the Z_{max} increase from 1.0 m to up to 1.3 m in the northeastern Middle Bay area. If the annual mean K_d is decreased by 20 % through a watershed restoration or improved community stewardship, the Z_{max} of these Point aux Chenes Bay areas will also increase by 0.3 m, which will result in up to a 50 m extension of SAV growth into the deeper water. Assuming light absorption is the prevailing limiting factor, this would result in a 35% increase in the potential SAV habitat, from approximately 1700 ha to about 2300 ha.

As demonstrated in Lake Pontchartrain and Grand Bay NERR, the PSAV model will serve as a useful tool in coastal SAV restoration projects by aiding in selection of potential restoration sites and in predicting the extent of SAV habitat gain after restoration. The following information will be collected through future studies to refine the model: (1) the relative PAR extinction caused by phytoplankton chlorophyll a, suspended sediment, dissolved organic carbon, and epiphytes; (2) desiccation tolerance of SAV at various levels of air temperature/humidity, air exposure duration, and epiphytic overgrowth; (3) changes in SAV light requirements at various growth stages; (4) SAV wave tolerance in relation to their morphology and growth stage; and (5) effects of shoreline modification on water clarity and wave stress.

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Hyun Jung Cho
Department of Biology
Jackson State University
1400 Lynch St.
Jackson, MS 39217, USA
Ph (601) 979-1814
Fax (601) 979-5853
E-mail: hyun.j.cho@jsums.edu