Stressor-Response Relationships for Habitat Alteration: Bay Scallop Habitat Assessment Models (WQ MYP)

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Agency Problem

A's Office of Water (OW) has primary regulatory responsibility for protecting the ological integrity of the Nation's aquatic resources and ecosystems. Although the ency has not traditionally focused its regulatory, policy and research efforts on habitat eration as a stressor, a number of factors converge to justify a new EPA emphasis on bitat issues. These include the mandate of the Clean Water Act (CWA) "to restore d maintain the physical, chemical, and biological integrity of the Nation's waters" and t habitat alteration is a commonly-cited cause for failure of aquatic systems to meet signated uses. In response to its need to develop ecological criteria to assess the role essential habitat in maintaining healthy populations of fish, shellfish and aquatic-pendent wildlife, NHEERL's Habitat Alteration research is providing approaches and thods to assess critical habitats and their ability to sustain fish, shellfish and aquatic-pendent wildlife.

Research Goals

e Aquatic Stressors Framework describes research to understand the relationships between y stressors of concern for EPA's Office of Water and responses of populations of fish, llfish, and aquatic-dependent wildlife. The goals of this research program are:

- Develop methods for predicting biological effects of habitat alteration
- Determine how populations of fish, shellfish, and aquatic dependent wildlife respond to abitat alteration

aditionally, bay scallop (*Argopecten irradians*) habitat research and restoration efforts have cused on the scale of the habitat patch, most often eelgrass. These efforts have met with ited success, and the question arises as to whether these efforts have been conducted at the propriate scale and level of complexity. This research project is developing habitat models the bay scallop. We are interested in determining the ability of models to quantify scallop-bitat interactions; data for incorporation into the models are being collected at the scales of bitat patch (smallest scale), SAV bed (intermediate scale), and whole water body (largest le). Currently the main scallop modeling effort is directed at three levels: a habitat tability index (HSI), a matrix population model, and a systems model. Bay scallop larval nsport is being modeled in conjunction with the scallop-habitat models.

uestion Being Addressed:

w can we use the knowledge of scallop-habitat relationships to guide habitat criteria velopment and inform and evaluate restoration efforts? Or put another way, if the Designated e is self-sustaining populations, then what attributes of habitat must be maintained or tored?

Methods/Approach

Methods for Modeling Scallop-Habitat Interactions at Multiple Levels of Complexity

Habitat Suitability Index

- The habitat suitability index model quantifies the relationship between various habitat attributes and scallop abundance.
- Field surveys (in conjunction with other scallop and SAV restoration projects) are examining the habitat attributes important to bay scallop populations in Martha's Vineyard, MA and Peconic Bay, NY (Fig. 1). Data from surveys in Nantucket, MA, conducted by an outside contractor, are being incorporated into the models (Fig. 1).
- Surveys and field experiments also are examining habitat effects on life history parameters of bay scallops (such as reproductive potential, survivorship, and growth) to help link the habitat suitability indices with the population model.

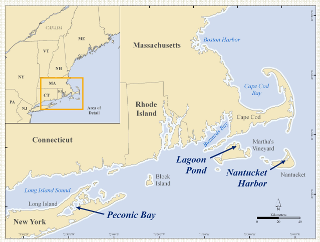


Figure 1. Map of the Northeast United States showing locations for the three main areas of sampling for data collection. Data are being used for all three scallop-habitat models.

Stage-Based Population Model

- The life history of *Argopecten irradians* was divided into five classes to capture the developmental stages of the bay scallop.
- The Town of Oak Bluffs and Martha's Vineyard Commission are interested in determining the impacts of habitat alteration on bay scallop populations and the minimum population size needed to maintain their populations. They are assisting with the dive surveys and data collection.
- Collaborators from the Peconic Bay Estuary Program in Region 2 are conducting experiments to determine the survivorship of bay scallops in different habitat types and to determine the extent to which movement is important in scallop populations.
- Rate coefficients are being used to describe transitions between stage classes (Fig. 2). Transition rates in the scallop model are assumed to be constant with respect to time, density, and general environmental conditions for the base model, but can be varied as a function of habitat loss in future models.

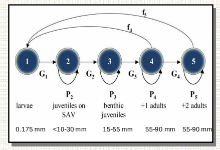


Figure 2. Life cycle representation of the stage-based population model for *Argopecten irradians* with a 2-week time step. G_i is the probability of an individual surviving to the next stage class during a time step; P_i is the probability of an individual surviving and remaining in that stage class during a time step; f_i is the reproductive output of an individual in that stage class during a time step.

Systems Perspective of Scallop Habitat

- This model links habitat alteration effects on scallop populations with ecosystem-scale environmental attributes (Fig. 3). The population model is embedded within the systems model.
- The model includes ecosystem linkages at all trophic levels and all habitat types, and evaluates scallop survival in relation to climate, watershed land use, water quality, refugia, food availability and predation
- The model will be run both over time and in spatial context and uses data collected from historic literature, dive surveys, field experiments, and other models such as the larval transport model.

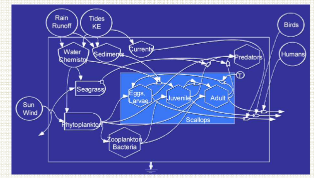


Figure 3. This simplified version of the model demonstrates the complex pathways and potential indirect effects of population response to multiple stressors, and shows how different habitat components can mediate this response.

Historical Assessment of Bay Scallop Abundance and Eelgrass Habitat

Historical data is being examined to see if there is a correlation between eelgrass habitat and bay scallop abundance in the past. Bay scallop catch records are available by town in Massachusetts from the 1960s to present. Bay scallop catch records for particular shellfish sites (*i.e.* pond, harbor, bay) are rare. All the catch records are considered estimates, not exact counts, but are useful for looking at trends. The catch records compiled by the towns are separated into commercial and recreational catch. The commercial catch records are considered more reliable because the towns generally used written reports from the commercial fishermen, whereas different methods have been used to estimate the recreational catch. Digital maps of historical eelgrass extent in Massachusetts exist for 1951 (not complete), the 1980s (not available for Nantucket and Martha's Vineyard), 1995, and 2001. The next step is to determine the best way to look at the relationship between bays scallop catch data and eelgrass extent.

Physical Modeling of Larval Transport

- Bay scallop larval transport and dispersion are being modeled for Lagoon Pond because preliminary results indicate that something other than habitat might be controlling juvenile scallop abundance.
- In the model, flow field is modeled with two-dimensional numerical models and first order death rate is calculated to account for loss of larvae after spawning (Fig. 4).
- Dispersion coefficients are being studied and calibrated, and patterns of larval distribution will depend on the point of larval release (i.e., location of spawning adults).

Hydrodynamics → Transport → Larvae

Circulation, Mixing, Death

$$\partial c/\partial t + \partial(u_i\, c/\partial x_i) = \partial(D_{ij}\ \partial c/\partial x_j)/\partial x_i - S$$

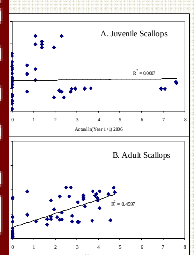
Time, Space

Figure 4. This is the equation for the 2-D numerical model illustrating the hydrodynamic parameter in red, the transport parameter in green and the larval parameters in blue.

Results

Habitat Suitability Index & Dive Survey Results

- sed on surveys of scallops and habitat in Lagoon Pond, MA, we developed models for th juvenile and adult scallops.
- e models' predictive ability for juvenile scallop abundance was poor, suggesting that mething other than specific habitat controls juvenile scallop abundance (Fig. 5A). esence or absence of scallops was correctly predicted 53% of the time.
- e models' predictive ability for adult scallop abundance was relatively good, with adult undance correlating positively with submerged aquatic vegetation and negatively with e sediments (Fig. 5B). For the adult model, presence or absence of scallops was correctly dicted 94% of the time.



ure 5. Predicted vs. actual bay scallop abundance for Lagoon Pond. Predicted values are based on an eelgrass algae model calculated with multiple linear regression.

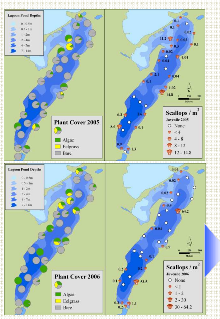


Figure 6. Vegetation type and location of juvenile bay scallops in Lagoon Pond in 2005 and 2006.

Most significant findings from dive surveys:

- Most scallops found in 1-5 m depths (Fig. 6) in all types of habitats (Fig. 7).
- Larger scallops found on northern & eastern side of pond Fig. 6).
- Highest abundance and smallest sizes of scallops were not necessarily associated with vegetation (Fig. 6).
- Local circulation patterns might be important to define scallop locations in Lagoon Pond.

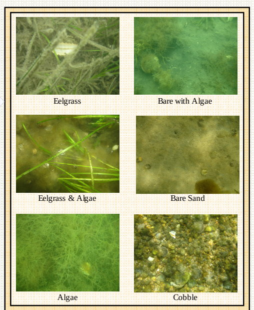


Figure 7. During the dive surveys in Lagoon Pond, bay scallops were found in a variety of habitats.

Stage-Based Population Model & Systems Perspective

- The population and systems models are being constructed at the same time.
- Initial conceptual models have been developed for the population and systems models. We are currently determining important pathways and values for the rate coefficients that will be used in the models.
- Collaborators in Peconic Bay had weather-related problems with the initial experiments conducted in 2006. A second round of experiments is being conducted this year and data from those experiments will be incorporated into existing models.

Historical Assessment of Bay Scallop Abundance and Eelgrass Habitat

Examples of the type of data available are shown for two towns in Massachusetts, Wareham and Marion.

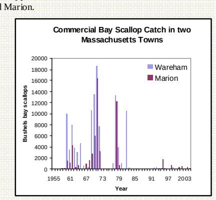


Figure 8. Historical commercial bay scallop catch records for Wareham and Marion, Massachusetts. For both towns, scallop catch peaked in the 1970s and declined dramatically to present day. (No bar indicates data were not reported.)

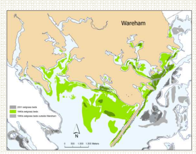


Figure 9. Map of eelgrass beds in Wareham, MA waters shows that eelgrass beds covered a considerably smaller area in 2001 (207 hectares) than in the 1980s (912 hectares). (In the 1980s coverage, we excluded eelgrass beds with less than 30 percent cover.)

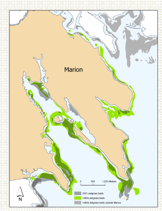


Figure 10. Map of eelgrass beds in Marion, MA waters shows that the beds in the 1980s are similar in location and area (297 hectares) to those mapped in 2001 (206 hectares). (In the 1980s coverage, we excluded eelgrass beds with less than 30 percent cover.)

Historical References:

1980s Eelgrass: Costa, J.E. 1988 Eelgrass in Buzzards Bay: Distribution, Production, and Historical Changes in Abundance. EPA 503/4/88-002 204 pp. http://www.buzzardsbay.org/eelgrass-gis-data.htm

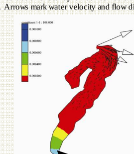
2001 eelgrass: MassGIS: Eelgrass DEP, February 2006 http://www.mass.gov/mgis/eelgrass.htm

Bay Scallop Catch Records: Massachusetts Division of Marine Fisheries, South Shore Field Station, Pocasset, MA

Physical Modeling of Larval Transport

- An initial, unrefined larval transport model has been developed for Lagoon Pond based on a transport model that was developed as part of the Nutrient Effects Research effort at AED.
- When scallop larval release is at the southern end of the pond, the highest concentration of larvae appears to stay at the southern end of the pond (indicated by the blue color in Fig. 11).
- When scallop larval release is at the northern end of the pond, then the highest concentration of larvae is found in the central area of the pond (indicated by the dark blue color in Fig. 12).

Figure 11. Modeled concentration of scallop larvae 108 hours after release of 10^6 larvae from the starred location. Arrows mark water velocity and flow direction and indicate flood tide.



Point of larval release

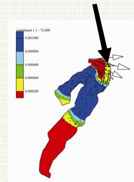


Figure 12. Modeled concentration of scallop larvae 72 hours after release of 10^6 larvae from the starred location. Arrows mark water velocity and flow direction and indicate flood tide.

Impacts and Outcomes

EPA Regions and State managers lack tools to regulate habitat alteration, and habitat alterations are difficult to reverse. Therefore, there is a need to improve assessment methodologies, diagnostic capabilities and ecological criteria for managers to be able to protect and restore habitats to meet designated uses. This research is producing the knowledge of scallop-habitat relationships needed to guide criteria development and inform and evaluate restoration efforts (Fig. 13). The three-tiered modeling approach will allow us to represent combined interactions of all scallop-habitat relationships, link habitat alteration with demographic attributes of the population and combine habitat alteration effects on populations with ecosystem-scale environmental attributes. Similar approaches can be applied to other species and habitats, thereby enhancing population sustainability as affected by habitat alteration.

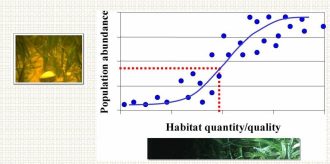


Figure 13. Conceptual example of using population and habitat data to develop a stressor-response relationship between scallops and SAV quantity or quality. These types of relationships can be used to determine the impacts of habitat alteration or in establishing restoration benchmarks.

Future Directions

- Verify the larval transport model and relate the model to bay scallop restoration activities currently underway in Lagoon Pond.
- Incorporate data being collected from the various dive surveys and experiments into the conceptual models to further develop the population and systems models.
- Examine watershed-level factors that might be influencing scallop distribution and explore the use of terrestrial techniques for analyzing habitat connectivity.
- Quantify ecosystem services bay scallop beds and their associated habitats provide to people.
- Determine how readily this approach could be applied to other locations and adapted for other species.

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