A stage-based population model for bay scallops *Argopecten irradians* and implications for population-level effects of habitat alteration

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BACKGROUND

The U.S. EPA has implemented a framework for ecological effects research on aquatic stressors, with the ultimate goal of developing approaches for protecting and restoring the ecological integrity of aquatic ecosystems from the impacts of multiple stressors, including habitat alteration. Habitat alteration is a serious problem: there is not much national consistency in protection of most habitats, 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 development for managers to be able to protect habitats and to restore habitats to meet designated uses. We are developing habitat stressor-response models for the bay scallop, *Argopecten irradians*, an economically and societally important marine species. The effects of habitat alteration on bay scallop populations will be quantitatively evaluated using a three-tiered modeling effort: a Habitat Suitability Index (HSI), a matrix population model, and a systems model.
This poster describes the bay scallop population model in detail.

INTRODUCTION

- Habitat quality and quantity are required for the maintenance of many populations of valued aquatic species. Essential habitats of fish, shellfish, and aquatic-dependent wildlife populations have been and are being altered by a wide array of anthropogenic activities.
- Research is needed to quantitatively link alterations in key habitats (*i.e.* grassbeds), to the population response (*i.e.* bay scallops). The resulting stressor-response relationships can be used as a scientific basis for implementing policies and regulations to protect populations of fish, shellfish, and aquatic-dependent wildlife.
- Population models allow us to examine population-level consequences of changes in habitat and associated life support functions in the context of species' demographics.

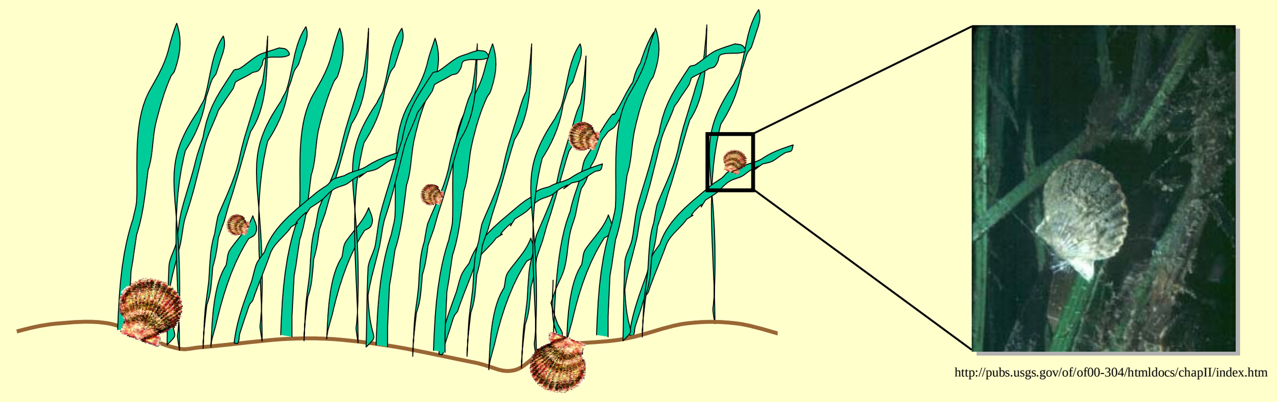

Figure 1. *Argopecten irradians* juveniles settle onto SAV blades as they transition from planktonic larvae to epibenthic adults.

Biology of *Argopecten irradians*

- *Argopecten irradians* commonly inhabit shallow bays and coves along the Atlantic coast of the United States.
- Bay scallops can be considered the closest species to an obligate SAV resident (Laney 1997), as juveniles primarily utilize SAV blades for settlement substrates (Fig. 1). Thus, SAV habitat is essential as individuals transition from planktonic larvae to epibenthic adults.
- Because this species has a short life span of 26 to 30 months, it is vulnerable to habitat alteration that causes loss of critical SAV habitat for juveniles. Each year class is almost entirely dependent on the spawning efforts of the previous year class, and the population will cease to exist if the spawning effort of an entire year class is lost unless larvae recruit from a distant location (Wenczel *et al*. 1994).

Table 1. *Argopecten irradians* Life History

Stage	Size	Age	Survivorship	Fecundity
1 larvae	0.175 mm	0.25-0.5 mo	0.001%	0
2 juveniles on SAV	<10-30 mm	0.5-2.5 mo	20%	0
3 benthic juveniles	15-55 mm	2.5-12 mo	20-50%	0
4 +1 adults	55-90 mm	12-24 mo	10-20%	12.6×10^6 - 18.6×10^6
5 +2 adults	55-90 mm	24-30 mo	0%	6.9×10^6 - 10.2×10^6

METHODS

- The population-level effects of habitat alteration can be examined by using population projection matrix models. We are developing these models to guide our scallop-habitat research activities, rather than to forecast actual field population dynamics.
- We constructed a staged-based population model (base model) for bay scallops, programmed in Microsoft Excel 2000 using the Pop Tools Add-In package.
- Model parameter estimates were derived from demographic life history information from the literature. A literature review revealed information on scallop reproductive parameters (Bricelj *et al*. 1987) but generally little information is available for survival parameters for the different stages.

Stage-Based Model

- The life history of *Argopecten irradians* was divided into five classes to capture the developmental stages of the bay scallop (Table 1).
- Rate coefficients were used to describe transitions between stage classes (Fig. 2). Transition rates in the scallop model were 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.
- The finite population growth rate (κ) calculated for each habitat alteration scenario can then be used as a measure of population level effects resulting from habitat loss.

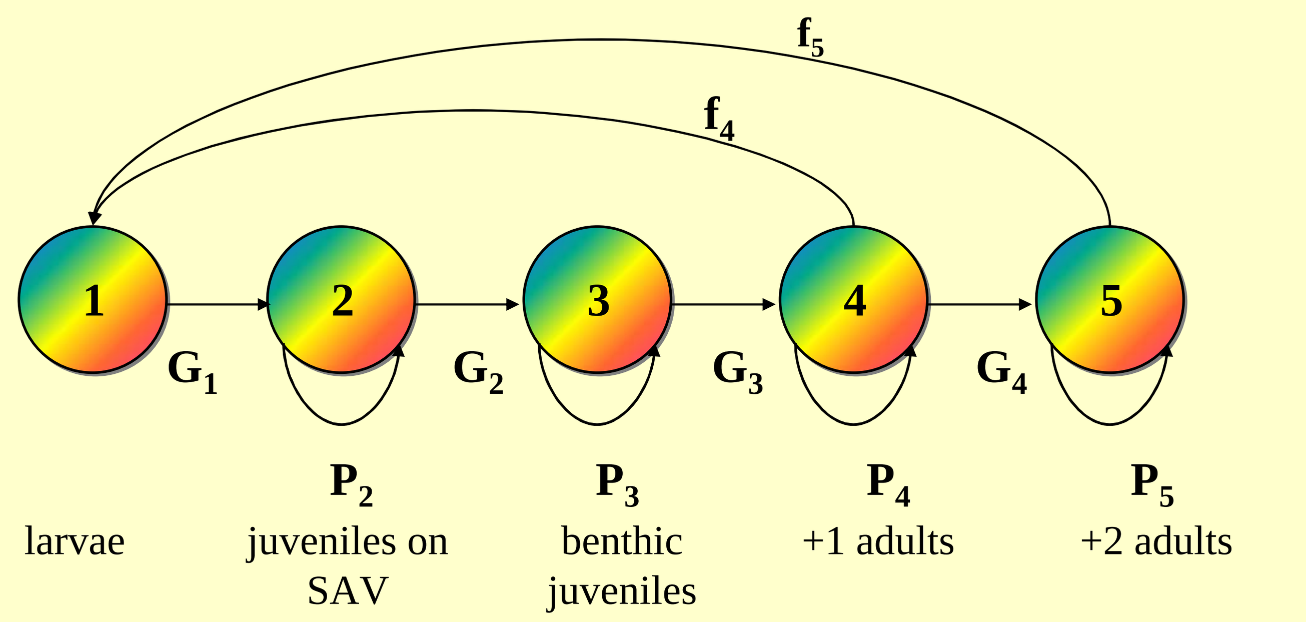

Figure 2. Life cycle representation of the stage-based population model for *Argopecten irradians* with a 2-week time step. G_i is the probability of an individual surviving to the next stage class during a time step; P_i is the probability of an individual surviving and remaining in that stage class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

RESULTS: Perturbation Analysis

- Used to evaluate how sensitive the annual population growth rate (κ) is to a change in survival of the juvenile stage that settles on SAV (P_2).
- The time step-specific survival probability of juveniles on SAV was varied (0%, 10%, 20%, 30%) and κ was calculated (Table 2).

Table 2. Perturbation Analysis for *Argopecten irradians* Stage-Based Model

Survival probability (P_2)	κ*
0.01	0.096
0.1	0.973
0.2	2.231
0.3	3.889

* κ > 1 population projected to increase
κ < 1 population projected to decrease
κ = 1 population projected to remain constant

- A small change in P_2 results in a large change in κ.
- Results underscore the importance of life stage most strongly dependent on habitat (*i.e.* SAV blades) for scallop population maintenance and growth.

Incorporation of Habitat Alteration Effects into the Model

- The HSI combines the interactions of key environmental variables into an index that predicts the ability of a habitat to support a particular species.
- HSI results will be used to modify the population model, making it a function of the habitat. For example, the effects of different life-support functions of the vegetated habitat (Fig. 3) on bay scallop survival probability can be determined.

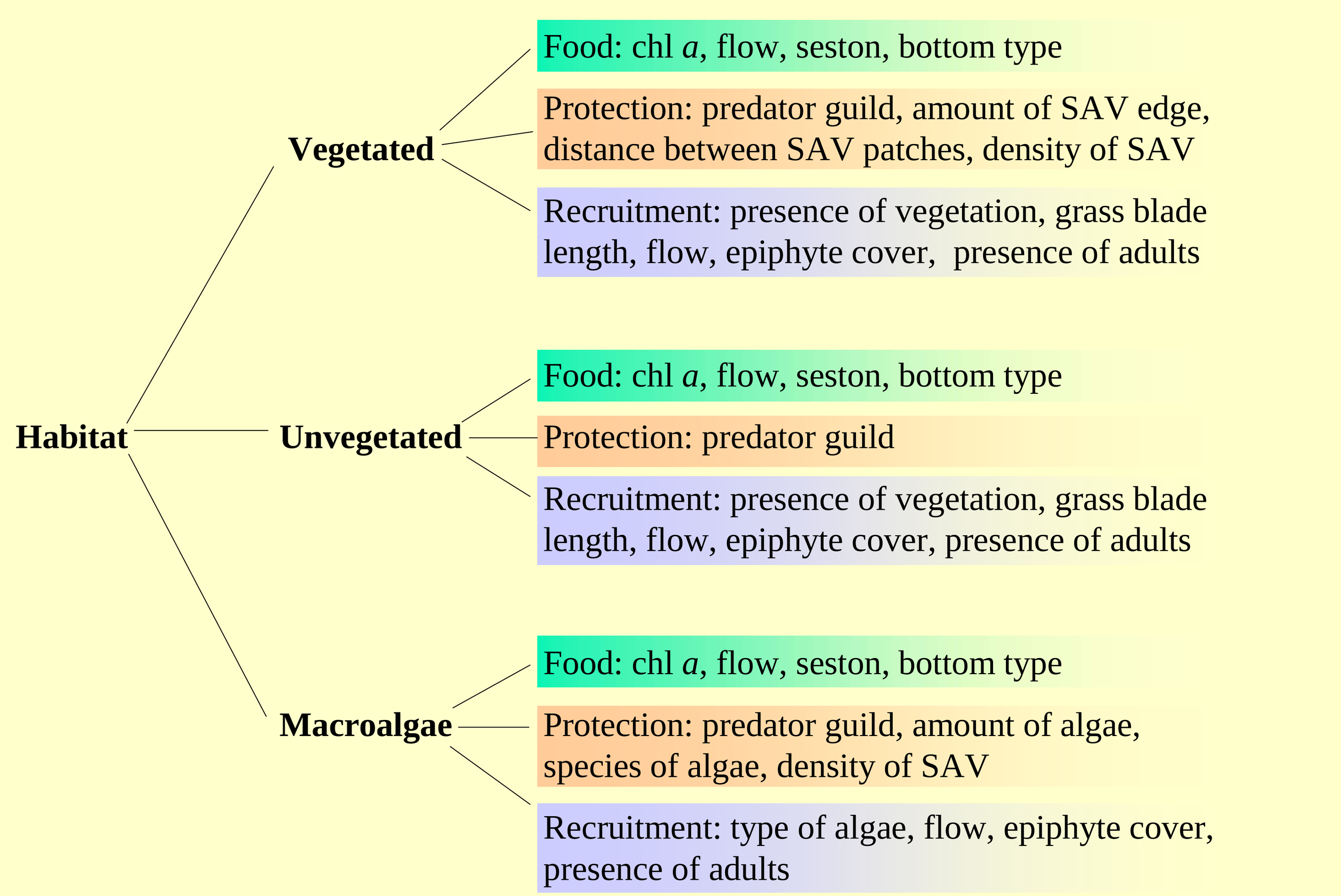

Figure 3. Potential life support functions of different habitat components encountered by bay scallops.

FUTURE RESEARCH

- We are planning field surveys and laboratory and field experiments to refine the HSI and population models.
- By assuming a closed population and knowing settlement density on SAV blades, we can attempt to calculate the minimum SAV density or areal extent necessary to support a self-sustaining population of bay scallops (where κ = 1).
- Ultimately, the system model will be constructed to incorporate the complex pathways and potential indirect effects of multiple stressors on the population, and demonstrate how different habitat components can mediate the bay scallop response to habitat alteration.

Application of the Models

- 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 (Fig. 4).

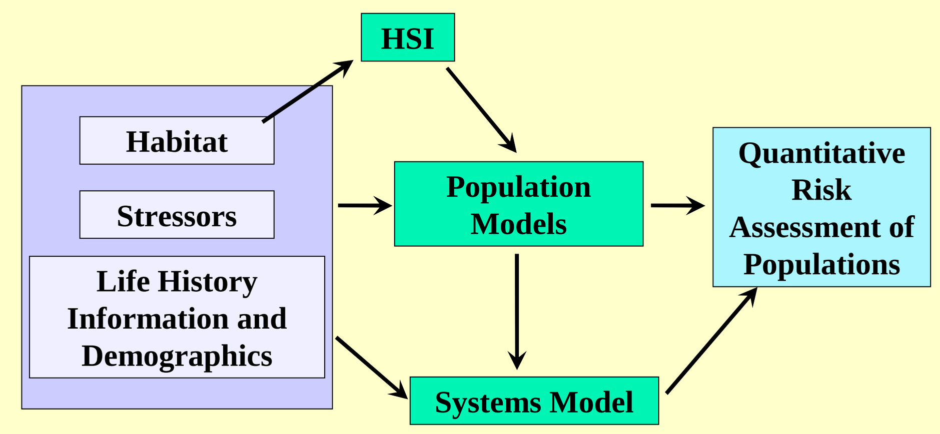

Figure 4. Three-tired modeling approach that leads to quantitative risk assessment of populations.

Relationship of HSI to Stressor Response Models

- The species' habitat preference can be presented as a response to differences
in each habitat variable. This response can be represented as a curve, with values of the habitat attribute on the x-axis and the species' use values on the y-axis (Slauson 1988).
- Ultimately, habitat criteria can be based on numeric cut-offs from relationships between stressor (habitat alteration) and response (fish, shellfish, and wildlife) for habitat-specific designated uses (Fig. 5).

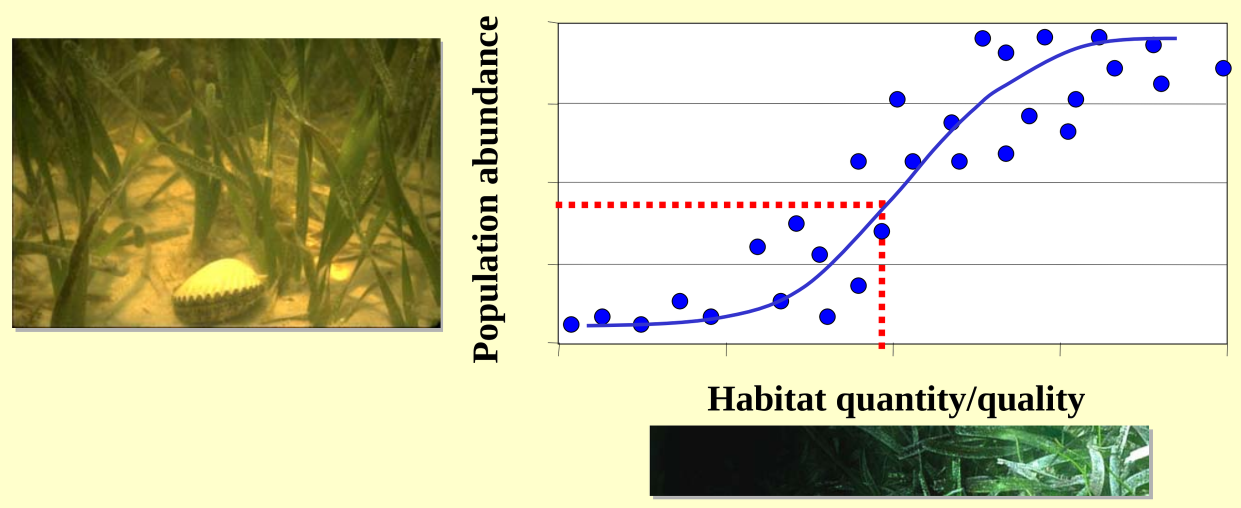

Figure 5. Conceptual example of using population and habitat data to develop a stressor-response relationship between scallops and SAV quantity or quality.

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