PEEIR

Pacific Estuarine Ecosystem Indicator Research Consortium

Models Relating Indicators of Physiological Condition to Population Responses

Issue

The most interesting questions regarding ecosystem health address features of populations and communities: are certain species declining, is there a robust food web, is species diversity high, etc.? However, with the exception of diversity, such characteristics are difficult to quantify directly unless the changes are dramatic and fast. PEEIR has focused much of its attention on indicators of the physiology and performance of individuals. These measures can be obtained much more rapidly than assessments of a population's viability over multiple years and decades, and they are more easily linked to specific stressors. But can stressors that impact individuals also predict important properties of populations and communities?

Approach and Rationale

Sensitivity analysis quantifies the extent to which stressor-induced changes in individual physiology and performance, as measured by individual indicators, leads to changes in population and community performance, as described by population endpoints. Proportional changes in the endpoints are associated with proportional changes in the individual indicators, often termed elasticity. Because most of the endpoints are difficult to quantify directly, we used mathematical models to investigate the relationship between the indicators and the endpoints.

For the resident fish indicator (longjaw mudsucker, *Gillychthys mirabilis*), we used "dynamic energy budget" models to link individual performance to growth and reproduction (Link to Modeling Value Added); these were coupled with mortality models that included size-specific predation and direct effects of stressors on individual survival (Figure 1). The various individual indicators (Link to Fish Integrated Indicators) are correlated with various parameters in the model; the endpoints were determined by the model. Thus, we can mathematically map the relationships between changes in the indicators and changes in the endpoints.

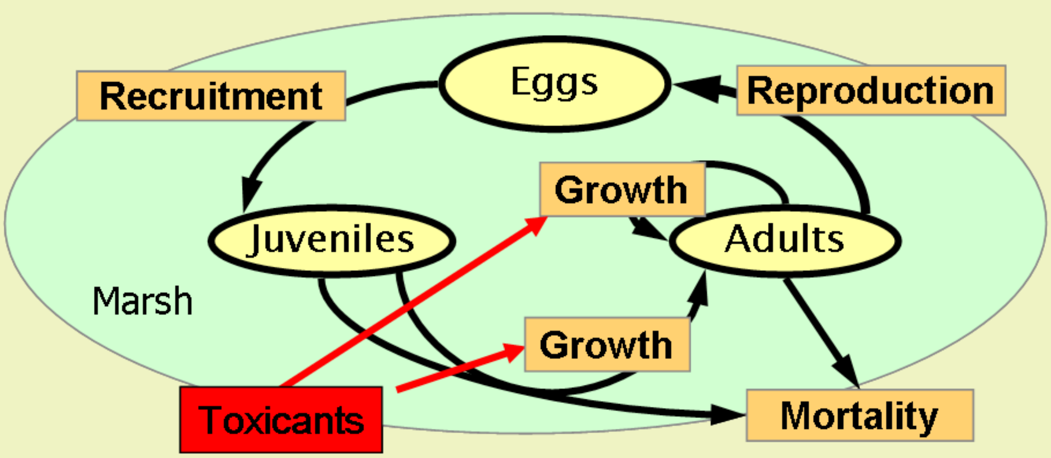

Figure 1. Schematic view of estuarine fish life history. Growth depends on temperature, food availability, and sublethal stressor burden; mortality is caused by starvation, predation, and lethal stressors, and is often size dependent. Reproductive output is strongly size-dependent. Eggs and very young fish (larvae) may move between nearby marshes.

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Population endpoints include:

- Population size structure
  - frequency distribution of body sizes in the population,
  - integrated measure of growth and survival;
- Lifetime reproductive success
  - number of offspring produced by an average individual in its lifetime,
  - integrated measure of individual performance;
- Short-term population growth rate
  - population growth over one year; affected by size structure as well as demography,
  - measure of population's ability to respond to environmental perturbations;
- Long-term population growth rate
  - long-run exponential growth rate, in absence of density dependence; independent of population size structure.

Findings and Impact

We parameterized the growth model using the longjaw mudsucker, and we estimated survival from mark-recapture data on this species at our field sites. Fecundity was assumed to be limited by the number of burrows available to the fish. We investigated an effect of a toxicant that reduced assimilation efficiency and increased the maintenance cost. Because of the density dependence, population density did not change. However, the size structure was markedly changed, so that the mean individual size was lower (Figure 2). The result was that a 20% reduction in feeding and maintenance efficiency caused a 50% reduction in population biomass.

Applications

This approach will be useful to agencies seeking to understand the population consequences of observed changes in the condition of individuals.

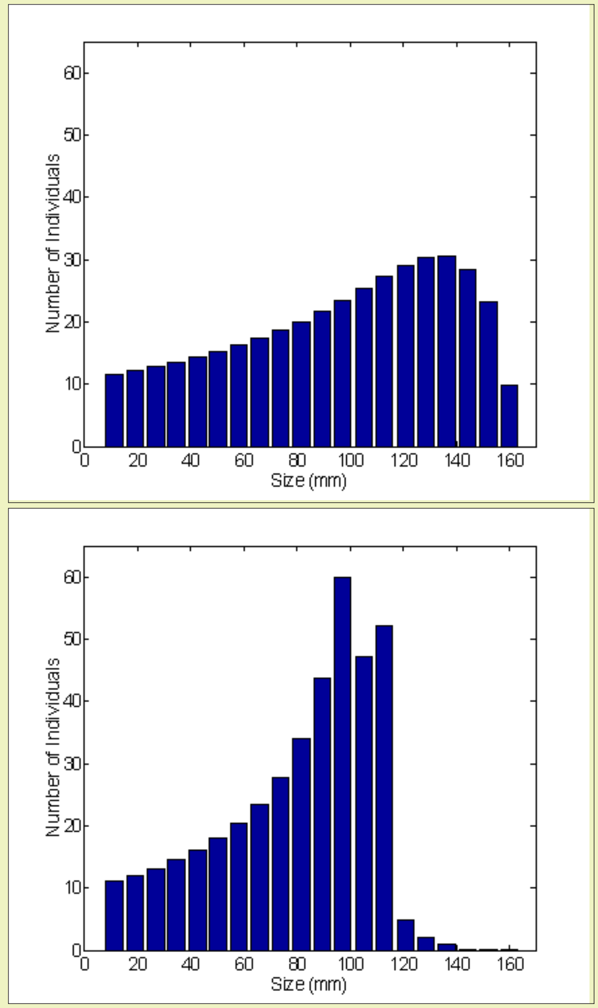

Figure 2. Stable size distribution of a modeled mudsucker population not subject to toxicants (top) and subject to a toxicant that reduces feeding efficiency by 20% and increases maintenance costs by 20% (bottom).

Publications

Please contact lead author for status of manuscripts in preparation.

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