MODELING POPULATION-LEVEL RESPONSES OF ATLANTIC CROAKER TO ENDOCRINE DISRUPTING CHEMICALS USING LINKED SIMULATION MODELS AND LABORATORY STUDIES

Cheryl A. Murphy
Department of Oceanography and Coastal Sciences
Louisiana State University
Baton Rouge, LA 70803
Tel: 225-578-5970
Fax: 225-578-6513
email: cmurph4@lsu.edu

Kenneth A. Rose
Department of Oceanography and Coastal Sciences
Coastal Fisheries Institute
Louisiana State University
Baton Rouge, LA

Sandra L. Diamond
Department of Biology
Texas Tech University
Lubbock, TX

Lee A. Fuiman
Marine Science Institute
University of Texas
Port Aransas, TX

Peter Thomas
Marine Science Institute
University of Texas
Port Aransas, TX

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Introduction

The influx of man-made chemicals into the environment since the beginning of the Industrial Revolution has produced many unexplained detrimental effects on wildlife populations (Colborn *et al*., 1993). Moreover, chemicals that result in endocrine disruption are receiving increasing attention. However, endocrine disruption as a cause of population decline in fish has been difficult to ascertain because most of the adverse effects on individuals are subtle or sublethal, and are small relative to other sources of population variation. Since endocrine disrupting chemicals (EDCs) were first recognized, numerous biomarkers have been measured that demonstrate abnormalities in fish exposed to industrial and domestic wastes (e.g. vitellogenin production in male fish). These biomarkers appear to correlate with decreased fertility, but to date, few studies directly link adverse effects of EDCs to fish population response. We use a combination of laboratory studies, nonlinear statistical analysis, and individual-based and matrix projection modeling to link lethal and sublethal effects of endocrine disrupting chemicals to fish population dynamics (Fig. 1). We demonstrate our approach using the effects of PCBs on Atlantic croaker (*Micropogonias undulatus*).

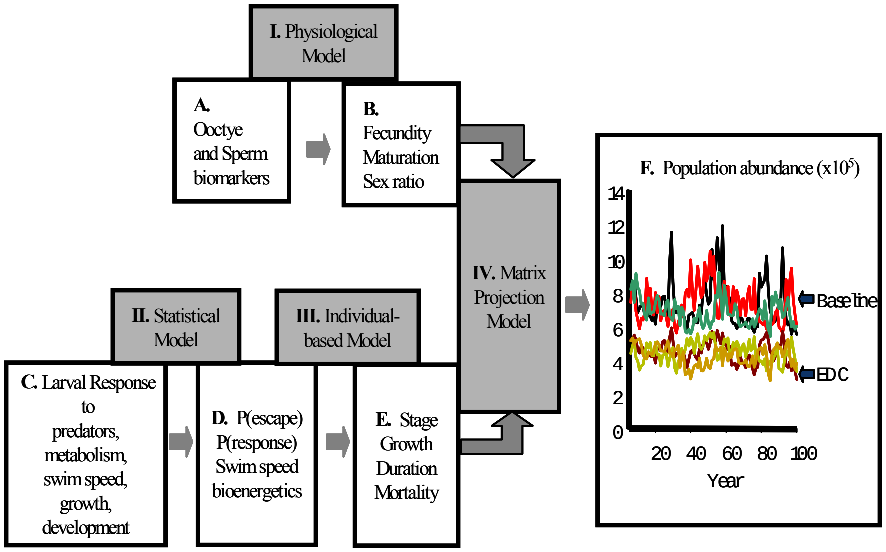

Figure 1. Toxicological endpoints measured in the laboratory linked to four models that culminate in a projection of Atlantic croaker population abundance over time.

Model I -Physiological Model

We conducted laboratory toxicity experiments on Atlantic croaker to compare commonly measured biomarkers (e.g., changes in steroid levels, estrogen receptor concentrations, and vitellogenin production (Fig 1A)) between control and PCB-exposed fish. In conjunction with these biomarkers, we also measured fecundity, oocyte maturation, fertilization success, and hatching success (Fig 1B). We used regression tree methods and neural network analysis to quantify the relationships between the biomarkers and the number of viable oocytes produced by PCB-exposed and control fish. We then use the changes in the number of viable oocytes (fecundity) as an input to the matrix projection model to simulate PCB exposure (Fig 1 IV).

Model II - Statistical Model

We performed behavior experiments using larval croaker spawned from control and PCB-exposed adult females. We measured response that included routine swimming speed and the timing and speed of evasive responses to artificial predators (using visual and vibrational stimuli). These behavioral responses for control and PCB-exposed larvae (Fig 1C) were then used with a statistical model developed by Fuiman,*et al.* (in prep) to determine how changes in swimming speed and predator avoidance behavior due to parental PCB exposure translate into the probability of escaping a real fish predator (Fig 1D).

Model III -Individual-Based Model

We used an individual-based model of a larval fish cohort that simulates larval encounter and capture of zooplankton prey (resulting in larval growth) and encounters and capture by individual invertebrate and fish predators (resulting in larval mortality). Swimming speed and probability of escaping a real predator (from the statistical model Fig 1D) are inputs to the individual-based model. We use the individual-based model to predict larval stage duration and survival in control and PCB-exposed larvae (Fig 1E). The changes in stage duration and survival due to PCB exposure are then inputted into the matrix projection model.

Model IV – Matrix Projection Model

We modified an existing life table developed for Atlantic croaker (Diamond *et* *al.*, 1999) to create a baseline matrix population model that uses a stage within age for YOY, and annual age classes for age-1 and older. The model simulates biannual spawning and three spatial boxes (YOY in North Carolina estuaries; YOY in Virginia estuaries; adults in the mid-Atlantic Bight). Model estimation and corroboration was based on data collected from fishery-independent surveys and published literature. Density dependence and stochasticity due to environmental variation were also incorporated. The matrix model was used to simulate the population dynamics under various combinations of feasible PCB exposures, other stressors, and natural variation (Fig 1F).

Simulations: Scenario and Results

To illustrate our approach, we simulated a croaker population for 100 years in which exposure to PCB was assumed to occur in North Carolina estuaries every year. We further assumed that PCB burdens in adult female spawners were completely eliminated with first spawn. Therefore, PCB effects were imposed on age-1 fecundity of individuals spawned in North Carolina, and imposed on the swimming speed and predator escape ability of the oceanic larvae spawned by these age-1 fish. Simulation results indicated a small, but consistent, reduction in the long-term average population abundance compared to baseline (unexposed) conditions. However, the reduction was masked by interannual fluctuations due to density-dependence and environmental variability.

Our analysis at this time is preliminary and demonstrates that it is possible to scale the sublethal tissue- and organism-level effects of EDCs to population-level responses. We emphasize that this analysis establishes proof of principle rather then predicting PCB effects on croaker. We are presently refining our analyses to enable us to make more accurate predictions of likely field effects.

References

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Diamond, S. L., Crowder, L. B., and L. G. Cowell. 1999. Catch and bycatch: the qualitative effects of fisheries on population vital rates of Atlantic croaker. *Trans. Am. Fish. Soc.* 128: 1085-1105.

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