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The economic value of freshwater inputs to an estuarine fishery

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ABSTRACT

The health of many estuarine and coastal ecosystems depends on upstream hydrology; however, there is limited information on the economic effects of restricting freshwater flow to the coast. We investigate the role of freshwater inputs on the blue crab fishery in Georgia, USA. Blue crabs are known to respond to salinity changes in the estuaries in which they reside, and declining freshwater flow to the coast over the last 50 years is correlated with increases in average estuarine salinity and falling commercial harvests. A structural, bioeconomic model reveals freshwater inputs have significant effects on fishery outcomes. Simulations of a counterfactual minimum-flow standard for three different rivers, set at 25% of 50-year averages, suggest such a policy would result in measurable benefits for the fishery, improving profits by 35% ($1.7 million) during the period 2002–2012 in the three fishing areas for which data were available. Aggregating the necessary additional water releases to achieve this standard yields an approximate average value of water of between $1 and $7 per acre-foot.

1. Introduction

Estuarine and coastal ecosystems depend on freshwater inputs to maintain moderate salinity [2], and reduced flows can substantially alter coastal ecology and the productivity of fishery resources [17,27,8]. In the southeast United States, rapid population growth and changing precipitation patterns have put significant pressure on surface water resources [32,44], in most cases reducing the average volume of freshwater reaching coastal areas and increasing estuarine salinity [2].

Blue crab fisheries along the coasts of the mid- and south-Atlantic and Gulf of Mexico have been identified as particularly vulnerable to elevated estuarine salinities, and reductions in catch have been correlated with reduced river flow to the coast since the 1990s [35,36,39,45]. However, existing studies on this topic have tended to either (a) use an iterative process to identify an *ad hoc* structural model relating harvest to river flow [36,45]; or, (b) examine one or multiple specific mechanistic hypotheses without extending the analysis to fishery-level questions [33,47].

We attempt to both improve upon these previous efforts, as well as fill a gap in the ecosystem service valuation literature. There is a large body of work on the value of coastal ecosystem goods and services [5], as well as the value of water [48]. However, to our knowledge, there has been no attempt to quantify the economic implications of freshwater interactions with coastal fishery performance[1], and water managers have almost universally ignored these

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[1] One related study was found during an exhaustive literature review. Fisher, Hanemann, and Keeler [12] examine the impact of freshwater flow on California's Central Valley salmon fishery using a simple simulation model. Chinook salmon migrate upriver to spawn, but are harvested in the ocean. They find likely benefits associated with increased freshwater release; however, economic benefits are not monetized, and the relationship between natural and hatchery salmon complicates the analysis.

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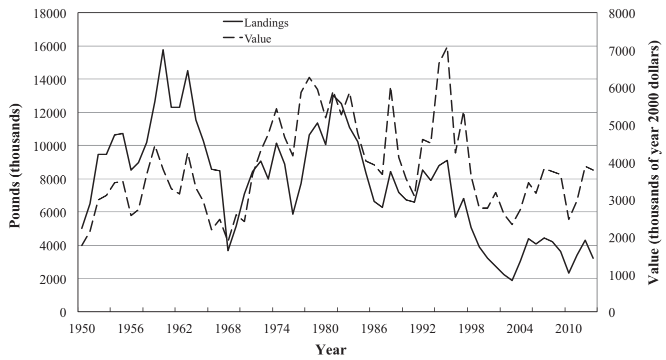

Fig. 1. Total landings of blue crab from 1950 to 2012. 1950–1988 from NMFS; 1989–2012 from GDNR.

impacts when setting minimum flow standards (MFSs) and issuing withdrawal permits for rivers entering the sea.[2] While freshwater inputs could be considered a driver of habitat size in estuarine environments, this study most closely fits within the research on the economic value of water quality improvements for marine fisheries [11,22,24,28]. This is because of the transient nature of salinity changes (the primary mechanism by which freshwater impacts the blue crab fishery), as well as the specific biological pathways by which salinity affects crabs (e.g., metabolic stress, disease).

In this paper, we develop a structural, bioeconomic model consisting of four interdependent equations describing the evolution of adult crab biomass, juvenile crab biomass, harvests, and effort, with the goal of more thoroughly investigating the biological mechanisms driving the relationships between crab populations and salinity levels, and the implications for fishery performance. The model is estimated using high-resolution, spatially-explicit data from the Georgia blue crab fishery. Specific, mechanistic hypotheses related to the impacts of salinity on unique crab life stages are embedded in this model. The parameterized model—along with a coupled model linking salinity to river flow in six estuarine systems (sounds)—is then used to simulate the effects of a hypothetical minimum flow standard (MFS) on fishery outcomes in three sounds fed by rivers. We find elevated salinity in these three sounds to be strongly correlated with nearby water flow readings, and model results reveal three crab life stages experience statistically-significant, negative impacts as a result.

The MFS simulation predicts sound-specific profits would have been 28–83% ($300,000–$900,000) greater had the standard been binding during the period 2002–2012. This final step allows us to generate estimates for the average value of additional water released in accordance with the MFS, which is found to be between $1 and $7 per acre-foot, on the same order of magnitude as estimated values for other uses of water in this region. These figures should aid policymakers in their efforts to allocate water to alternative uses, and contributes to recent calls for embedding ecosystem service measures in coastal planning efforts [23,4].

The next section provides a description of the commercial fishery in Georgia and its historical performance, a review of the biological motivations for specific hypotheses regarding salinity-crab hypotheses, and the relevance of this study in light of current stressors affecting surface water resources in the state. The bioeconomic model and description of the datasets used in the estimation are introduced in Section 3, followed by estimation results and a discussion of alternative model assumptions and structural specifications that were tested but ultimately rejected. Section 4 describes the counterfactual MFS simulation and discussion of results. Section 5 concludes.

2. Background

2.1. The Georgia blue crab fishery

The common blue crab (*Callinectes sapidus*) is known for its sweet, tender meat that—in lump form—is the basis of Chesapeake Bay Crab Cakes or, alternatively (and with a significant amount of effort) is picked apart at crab bakes every summer throughout the Atlantic and Gulf of Mexico coastal regions of the United States. The commercial fishery in Georgia is the second most valuable in the state [10], with revenues at nearly $4 million (year-2010 dollars) on landings of 3.2 million pounds in 2013.[3] This is despite a fall in landings since a modern high of 9.1 million pounds in 1995 (Fig. 1). By 2003, landings were under two million pounds, and a disaster was declared by the National Marine Fisheries Service [15].

The fishery is prosecuted exclusively by small vessels, often operated alone by captains. Traps with floats and juvenile escape rings are the only allowed gear. Crabbers are territorial in response to congestion externalities

[2] The few instances in which US jurisdictions enforce minimum flow standards to the sea are not the result of a thoughtful weighing of benefits, but instead almost always driven by litigation under the Endangered Species Act [2,36].

[3] Personal communication, NOAA National Marine Fisheries Service, Fisheries Statistics Division.