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Valuing water quality changes using a bioeconomic model of a coastal recreational fishery ☆

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Abstract

This paper develops and applies a structural bioeconomic model of a coastal recreational fishery. We combine a dynamic fish population model, a statistical model of angler catch rates, and a recreation demand model to estimate the value of water quality changes for the Atlantic Coast summer flounder fishery. The model predicts that improving water quality conditions in Maryland's coastal bays alone would have relatively small impacts on the fishery as a whole. However, water quality improvements throughout the range of the species could lead to substantial increases in fish abundance and associated benefits to recreational anglers from increased catch rates. We also estimate an alternative version of the catch function, with no direct measure of fish abundance included, and we compare results from this "reduced form" approach to results from our structural model.

Keywords: Bioeconomic model; Dissolved oxygen; Recreation demand; Recreational fishing; Summer flounder; Water quality

1. Introduction

Approximately 20 million people went saltwater fishing in the year 2000, making it one of the most popular outdoor recreational activities in the United States [24]. According to the US EPA, 51% of coastal waters are impaired for one or more human uses [48], and studies consistently demonstrate that water quality conditions affect recreation demand. There is a substantial body of research on the relationships between water quality and recreational fishing in particular. However, most previous studies focus on a single element in the chain of effects that connect water quality changes to the welfare of anglers, or they use a reduced form approach based on cross-sectional data on trip frequencies, expected catch, and water quality across fishing sites, thereby avoiding the measurement or modeling of fish abundance altogether. The result is a large number of studies

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that as a group indicate improvements in water quality may lead to substantial benefits for anglers, but individually are difficult to combine to evaluate specific water quality policies in a comprehensive manner.

In this paper, we develop and apply a structural bioeconomic model that integrates the major links in the chain of effects connecting water quality to angler welfare. First, we model the effects of water quality conditions on fish survival and abundance. Second, we model the effect of fish abundance and water quality on angler catch rates. Third, we model the effects of angler catch rates on trip demand. Combined, these form a dynamic bioeconomic model of the effects of water quality changes on recreational fishing.

We have adopted a structural modeling approach for several reasons. First, the available datasets were assembled independently and for purposes other than estimating a model for valuing water quality changes. In our experience this is a common scenario, so it is important to develop methods of integrating disparate datasets and models in an internally consistent way for policy analysis.

Second, the structural modeling approach we use provides the flexibility to evaluate a wider range of water quality policies than most previous models. We take advantage of a detailed water quality dataset to evaluate changes in water quality conditions on time scales as short as quarter hour intervals. Most previous models use average annual or single point in time measures of water quality conditions. The structural model also accounts for fish movements in and out of the study area, so it can be used to investigate the effects of the geographic scope of water quality changes in addition to the magnitude of the changes, unlike standard reduced form approaches. In addition, the structural model treats the recreational fishing sector and the commercial fishing sector separately, which can provide a platform for comparing water quality policies to fishery management policies.

Third, when analyzing a system of multiple interconnected sites, such as a coastal recreational fishery, it is important to distinguish between the short run and long run effects of water quality (and other habitat conditions more generally) on the species' abundance. Given a fixed total population size, the spatial relationship between abundance and water quality will depend on the behavioral responses of fish to the variation in water quality conditions and fish population density across all of the interconnected sites in the range of the species. Individuals will tend to spread out across the available habitat in such a way that balances the positive effects of good habitat conditions and the negative effects of crowding [10,41]. Changes in water quality will have a short run effect on the spatial distribution of individuals in the population through this habitat selection process, and a long run effect on the overall abundance through changes in survival or reproduction. In general the short run relationship between abundance and water quality need not be the same as the long run effect.[1] Thus, a reduced form approach that excludes potentially important dynamics that occur at other times in the species' life cycle can at best only implicitly capture the short run relationship and therefore will likely produce inaccurate forecasts of the long run effects of water quality changes.

In the next section we lay out a stylized bioeconomic model that describes how a recreational fishery evolves over time in response to water quality conditions and angler behavior. The model also provides a convenient organizational structure for discussing previous research on recreational fishing and the structural model developed in this paper. In Section 3, we apply our approach using data on water quality and angler catch rates in Maryland's coastal bays and a stated choice survey of anglers who target summer flounder on the Atlantic Coast. Section 4 summarizes the main results and concludes.

2. A dynamic model of a recreational fishery

Water quality may affect the site choices, trip demands, and ultimately the welfare of anglers through several pathways. First, water quality may affect fish abundance through its impact on the reproductive and survival rates of individual fish. Thus, the abundance of fish in time period t, A_t, will be a function of the abundance, the harvest, H_{t-1}, and water quality conditions, $\mathbf{Q}_{t-1}$, in the previous time period:

$$A_t = f_1(A_{t-1}, H_{t-1}, \mathbf{Q}_{t-1}). \tag{1}$$

[1] The short run (spatial) and long run (dynamic) relationships between fish abundance and water quality could diverge even in a steady-state situation. This could occur for at least two reasons: (1) water quality has different effects on different life stages of the species, and (2) per-capita reproduction or survival rates in pre-harvested life stages are functions of population density (i.e., are "density dependent").